Research Summary

South Carolina Department of Transportation | Office of Materials and Research

Project Information

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This final report is available online at:

http://www.scdot.scltap.org/projects/completed/

Assessment of Structural Degradation for Bridges and Culverts

Degradation of bridge components is an ongoing challenge facing the South Carolina Department of Transportation (SCDOT). Different methods are used in the United States to evaluate the condition of bridges and have yielded reasonable results. However, these approaches are time consuming, are inadequate for identification of some hidden defects, and may expose workers to passing traffic. Additionally, many maintenance activities will need to be conducted by a reduced workforce in the future. Efficient evaluation methods will become increasingly critical and a variety of evaluation techniques are available to save both money and time. Aerial drones, crawler robots, semi-autonomous jetyaks and related technologies are of interest to reduce time and increase safety for bridge and culvert inspections. Live load testing and long term monitoring of bridges are likewise of benefit to understand structural behavior and to address issues associated with load postings. A benefit cost analysis indicates that using aerial drones could significantly enhance the inspection of bridges, especially if SCDOT personnel are trained to operate the devices. Furthermore, acoustic emission assessment has potential for evaluation of distress in shear regions and for the assessment of bridges under ambient loading conditions.

Midsize aerial drone

Compact aerial drone

Crawler robot

Robot for culvert inspection

Problem

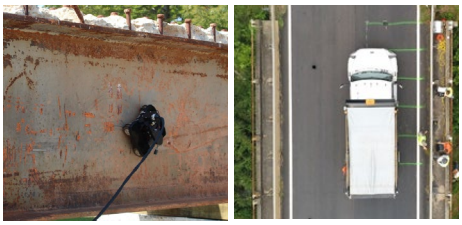
The deterioration of bridges and culverts presents a maintenance challenge for most transportation agencies and bridge owners. One aspect of condition evaluation is inspection, which is usually approached through visual and tactile means. These methods are time-consuming, subjective, challenging for difficult to access regions, and can be costly in terms of human resources and safety, sometimes requiring traffic control or closure.

Research

This project is motivated by a desire to identify bridge evaluation and inspection methods and new technologies to provide flexibility for inspection of difficult to access regions of bridges and culverts, and to

supplement current methods used by SCDOT while greatly minimizing or eliminating the need for traffic control.

Autonomous and semi-autonomous technologies have recently become commercially viable and are proving their usefulness in many industrial and other infrastructure applications, while other systems are in development. Among these are; a) aerial drones with image collection capabilities; b) robotic crawlers with or without end attachments to enable nondestructive evaluation; c) autonomous or semi-autonomous jetyaks with or without multi-beam or other similar technology for assessment of scour; d) robots for visual inspection of the interior regions of culverts; and e) other instrumentation for the evaluation of bridge response such as acoustic emission, strain gauges, and wire potentiometers.



Tethered crawler system (left); bridge live load testing (right)

To assess the feasibility of different evaluation methods for South Carolina bridges and culverts, a literature review was conducted to better understand the potential benefits and limitations of different technologies and devices. Several devices and technologies were tested in an outdoor controlled setting with different and commonly encountered bridge elements. Several vendors were invited to demonstrate technologies. Based on the findings, In-service bridges were then selected and used as testbeds to further evaluation technologies having potential for rapid evaluation of bridges and culverts. Furthermore, two in service bridges were selected for live load testing.

Results

Robotic systems can extend and improve upon the sensory capabilities of human evaluators, with different categories discussed below.

Aerial drones: Extension of and improvement upon sensory capabilities is obvious for this type of robotic system, with 30x optical zoom and infrared sensing widely available at reasonable cost. These capabilities are combined with ease of access to the underside of bridges and also from above. One challenge for bridges is the current requirement for tactile inspection, such as tapping of questionable areas with a coin or hammer. Among the nine evaluated consumer, custom, and industrial grade drones, aerial systems such as the Parrot Anafi and the Matrice 210 offer cost-effective and compact options. Importantly, the Parrot Anafi can be stable with and without GPS. The Matrice 210 is widely used in many industries that rely on infrastructure inspection and is robust and customizable.

Robotic crawlers: These systems offer advantages in terms of contact sensing, approaching or exceeding the capabilities of human evaluators. Though most systems have yet to be outfitted in this way, it is not difficult to imagine systems that could utilize impact echo or other 'touch like' inspection methods for concrete structural components. The systems investigated were aligned with inspection of steel components and were capable of being outfitted to address loss of section due to corrosion of steel girders or the extent of fatigue cracking.

Marine robotics: Jetyaks and similar systems allow for semi-autonomous inspection of bridge elements above the waterline and provide reasonable potential for assessing scour or precursors leading to scour. These systems can also serve as a platform for re-charging of aerial drones which is important for the inspection of longer bridges over larger bodies of water.

In the event that detailed inspection of culverts is desired, systems such as the Super Droid SCT-32-W Inspection Robot and the Super Droid MLT-42 W Water-tight Compact Inspection Robot are recommended for further consideration. These and similar devices have desirable features such as a 360-degree camera and supporting software.

Bridge live load testing provides valuable insight into structural behavior under known loading conditions that cannot be approached through visual or tactile inspection. Live load testing resulted in assessment of the joint efficiency the degree of restraint provided at boundaries. Acoustic emission provided insight into specialized regions of the bridges including the concrete bent caps. Further, acoustic emission monitoring appears well-suited to evaluation of bridge components under ambient traffic loading.

Value & Benefit

With a growing population and aging infrastructure, the SCDOT will continue to face challenges with inspection of bridges and culverts, and with load rating of bridges. Automation is changing the way in which all industries are meeting current and future needs. Robotic technologies such as aerial drones, robotic crawlers, and jetyaks as explored in this project offer the opportunity to extend the reach of human inspectors and to greatly reduce costs while increasing worker safety. Along these same lines, automated bridge evaluation through monitoring under ambient traffic loading offers potential to address load postings.

Widespread implementation of aerial drones is recommended to supplement bridge inspections. A database of photographic images gathered from aerial drones should be collected along with bridge inspection reports to enable automated image processing in the future. Live load testing should be continued. Acoustic emission data should be considered for areas where displacement-based sensors are less effective, and for the automated evaluation of distress in bridges under ambient traffic loading.

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