Evaluation of Bridge Movement Measurement Using GPS

tech transfer summary

GPS is a viable technology for high-accuracy/high-precision monitoring of long-term movements of bridge structures.

Problem Statement

Global positioning system (GPS) technology is a rapidly-emerging tool used throughout a variety of applications. Just two decades ago, GPS was not available for use other than by the US Department of Defense. Now, sub-centimeter GPS positioning capabilities are available to anyone with increasing precision likely to come. Costs for high-accuracy/high-precision global positioning equipment are comparable to, if not lower than, many other sophisticated measuring devices.

Given the recent technological advancements, GPS has the potential to be utilized in high-accuracy/high-precision monitoring of bridge movement. Few records have been found indicating prior testing of GPS as a viable option for bridge movement monitoring. In addition,, little background information currently exists detailing the configurations that may optimize the accuracy and precision of GPS data collection.

Objectives

A comprehensive research project involving all of the bridges at the I-80/I-235/I-35 interchange provided an excellent opportunity to compare the accuracies of GPS and total station measurements under real-world conditions. These were the objectives for this small part of the project:

- Determine how to best utilize GPS technology in monitoring bridge movements
- Identify GPS data collection configuration settings that optimize the precision and accuracy of collected data
- Compare precision and accuracy of bridge movement monitoring results between GPS and total station equipment for Bridge 0309 at the northeast junction of I-80/I-235/I-35 in Des Moines, Iowa

GPS antenna locations on Bridge 0309 with south abutment, left, and north abutment, right

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RESEARCH PROJECT TITLE
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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Research Description

Research included literature reviews, optimum configuration setting analysis, elevation mask angle testing (EMA), monthly data collection at Bridge 0309, precision analysis, and analysis of GPS data versus total station data. Comparisons of data accuracy were made for GPS antenna movements and for changes in length between the two abutment antennas.

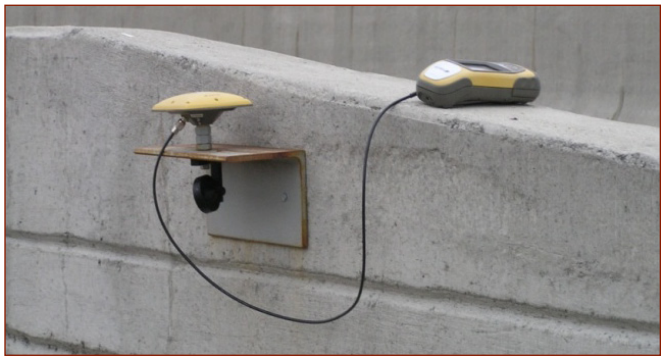
Literature reviews aided in determining the optimum settings for many of the configuration options available for GPS data collection. Theoretical analysis, as well as field experimentation, was conducted to determine one of the important configuration settings, the EMA.

Once a month for eight months (February through September 2011) GPS position readings were collected at Bridge 0309. These readings were taken at the same time as total station position data. By collecting GPS and total station data at the same time, position, length, and movement data can be compared with little impact from thermal movements.

Key Findings

- EMA settings are generally recommended to be set between nine and seventeen degrees above the horizon. Results of EMA testing concluded there is no noticeable accuracy difference for angles in this range.

- GPS results were more precise than total station results for monitoring the individual GPS antenna locations. GPS results yielded a 95 percent confidence interval of ±0.03 in. while total station results yielded a 95 percent confidence interval of ±0.1 in. One reason is because 150 GPS position readings were collected and six position readings were collected with the total station.



Total station prism and GPS antenna on Bridge 0309 at north abutment

Elevation mask angle (EMA) field testing

- Total station results were more precise than GPS results for monitoring the change in length between the two abutments. GPS results yielded a 95 percent confidence interval of ±0.05 in. while total station results yielded a 95 percent confidence interval of ±0.03 in.

- The rate of change of length between abutments was calculated to be 0.014 in. per degree Fahrenheit using the GPS and 0.018 in per degree Fahrenheit using the total station.

Implementation Benefits

GPS is a viable alternative to conventional forms of bridge movement monitoring. The ability to collect precise positioning data without ground-based benchmarks and during all types of weather conditions—and to remotely operate and analyze the GPS equipment in real-time—make this technology worth investigating further.

Remote monitoring of real-time performance will probably become an attractive alternative. One disadvantage is that the GPS must have an unobstructed view of the sky (i.e., cannot be placed under a bridge).

Implementation Readiness

Thermal movement monitoring on Bridge 0309 at the junction of I-80/I-235/I-35 in Des Moines has confirmed the prospect for future use of GPS technology in high-accuracy/high-precision structure movement monitoring applications. Further research can help refine GPS technology capabilities more fully in this field, including remote operation.