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OFFICE OF TRANSPORTATION SYSTEM MANAGEMENT

IMPLEMENTATION SUMMARY

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PROJECT COST:
$35,300

BL sensors are inexpensive and can be calibrated to compensate for their temperature sensitivity.

Putting Research into Practice: Lower-Cost WIM Sensors Need to Compensate for Temperature to Be Accurate

Investigators tested two approaches to compensate for the temperature sensitivity of low-cost weigh-in-motion sensors for permanent applications. This research developed a formula for correcting weights based on pavement temperature that produced a correct average of the weights.

What Was the Need?

Weigh-in-motion (WIM) systems provide detailed traffic information such as traffic volume, vehicle weight and vehicle classification. This information is valuable for transportation network planning and decision-making.

Most WIM systems utilize crystalline quartz piezoelectric sensors, which provide good-quality data, but at high cost. Quartz sensors cost about $27,000 per lane, plus installation. Piezoelectric polymer film sensors (also known as brass linguini, or BL, sensors) cost only about $2,000 per lane and have a longer working life.

Both types function by generating electric charge signals from the weight of a vehicle driving over them. BL sensors, however, are also sensitive to temperature, so changes in pavement temperature will cause them to generate electric charge signals that introduce error into the measurements. This inaccuracy has prevented widespread implementation of BL sensors for WIM.

Custom charge amplifiers, which remove the slowly generated charges in BL sensors caused by temperature changes, have been used in portable WIM systems to compensate for this temperature sensitivity. In initial testing, the portable BL-based systems performed as well as permanent quartz sensors under colder pavement temperatures, but did not perform well under warmer summer temperatures. MnDOT wanted to evaluate whether there are effective ways to compensate for pavement temperature changes so a BL sensor could produce reliable data in a permanent WIM installation.

What Was Our Goal?

The purpose of this project was to evaluate two options to resolve the temperature dependency issue: a charge amplifier and a mathematical approach that corrects weight measurements after data collection based on the measured pavement temperature.

What Did We Implement?

This project expands upon project 2012-38, "Development of a Weigh-Pad-Based Portable Weigh-in-Motion System," which investigated the use of BL sensors in portable WIM applications.

How Did We Do It?

Investigators established test sites on State Highway 61 north of Duluth. WIM #30, which employs quartz sensors, was used to provide baseline data. WIM #213, the site of a retired automatic traffic recorder 1.8 miles north of WIM #30, was selected for the BL sensor test. While there are two intersections between WIM #30 and WIM #213, neither crossing road carries much traffic, so traffic levels at the two WIM sites are comparable.

Both WIM sites collected usable data between December 2014 and October 2015. Investigators measured vehicle weights of class 9 trucks at the BL sensor site in two ways.

continued

"The BL sensors are much cheaper and last longer, so we could install these lower-cost systems on lower-volume roads and get a lot more systems out there to collect more data."

—Benjamin Timerson,
Transportation Data and Analysis Program Manager, MnDOT Office of Transportation System Management

"The charge-amplifier-based temperature compensation doesn't work for permanent sites because of the large temperature swings from winter to summer, but we were able to use pavement temperatures to adjust the distribution of measured weights to a correct average."

—Taek Kwon,
Professor, University of Minnesota Duluth Department of Electrical Engineering

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The charge amplifier compensates for temperature changes by removing slowly generated electrical charge signals from the BL sensors. But the large temperature swings experienced in Minnesota over the course of a year render BL sensors ineffective for permanent WIM sites.

First, they collected weights based on signals corrected by the site's charge amplifier. Second, they developed a formula to adjust the signals collected by the BL sensor itself based on pavement temperature. (They based this formula on a mathematical model that assigned the average weight of class 9 steer axles to temperature bins that increased by increments of 5 degrees Farenheit from minus 25 degrees to plus 100 degrees.) Investigators compared both sets of adjusted weights to the weights collected by the quartz sensor at various pavement temperatures.

What Was the Impact?

The charge amplifier approach did not successfully measure vehicle weights under the wide pavement temperature swings that Minnesota experiences over a full year. The average class 9 steer axle weight measured by the BL system with the charge amplifier ranged from 5,000 pounds at a pavement temperature of minus 22.5 degrees Fahrenheit to 20,700 pounds at a pavement temperature of 97.5 degrees, a weight increase of 314 percent. By comparison, the average weights measured by the quartz sensors over the same temperature range increased from 9,000 pounds to 11,200 pounds, a 24 percent increase.

The temperature-based calibration of the BL sensors, however, did produce reasonably accurate vehicle weight values. The measured axle weights increased at a slow but steady rate up to 38 degrees, and at a faster but still steady rate at warmer temperatures. Researchers could therefore define the relationship between average measured weights and pavement temperatures using a pair of simple linear equations.

While the calibrations of BL sensors produced average weights comparable to those measured by the quartz sensors, the variance in individual weights measured was greater for the BL sensors. This was an expected result because the sensor material in BL sensors is less uniform than in quartz sensors.

What's Next?

While no further research is currently planned, avenues of investigation that may have value include systems that measure left and right wheel paths separately to improve data quality and a test of whether quartz sensors can be installed below pavements like BL sensors to improve their longevity.

This Implementation Summary pertains to Report 2016-10, "Implementation and Evaluation of a Low-Cost Weigh-In-Motion System," published March 2016. The full report can be accessed at mndot.gov/research/TS/2016/201610.pdf.