CENTER FOR TRANSPORTATION RESEARCH

# PROJECT SUMMARY

Texas Department of Transportation

# 0-6873: True Road Surface Deflection Measuring Device (Phase 2)

## Background

Highway pavement engineers have always recognized the usefulness of pavement deflection data in evaluating and monitoring pavement response and structural conditions. The Texas Department of Transportation (TxDOT) is a leading agency in terms of using deflection data and developing and implementing devices to measure pavement deflections; TxDOT projects resulted in creation of the rolling dynamic deflectometer and the total pavement acceptance device. While these two devices have demonstrated their usefulness and capabilities, they do not measure actual pavement deflection under a moving axle load and operate at very low speeds. This deflection measure cannot be used for backcalculation of layer moduli and rehabilitation design. Therefore, this project was designed to create a novel sensing system capable of accurately measuring pavement deflection for network-level applications at higher speeds.

## What the Researchers Did

The researchers investigated use of high-performance laser rangefinders in combination with a ring laser gyroscope (RLG) for monitoring the deflection caused by a truck driving on a paved highway. The sensor system uses three measurement lasers: two lasers monitor the undeflected pavement surface, while the third monitors the deflection caused by the loaded axle. The final system contains four laser heads for optimization purposes. While the laser measurements are highly accurate, no current technology can determine the absolute position of a system with respect to an inertial frame of reference with the required precision and during the time required by both lasers to cover the deflection basin. These considerations mandated a physical coupling between sensors in order to reduce the degrees of freedom. The simplest mechanical coupling, a perfectly rigid beam, allows only six degrees of freedom. In addition, the location of the sensors with respect to a common moving frame is necessary for analysis and deflection estimation. This represents a major challenge for the mechanical fabrication of the beam in order to verify the rigid body assumption while accounting for the location accuracy evaluated at a micron level. The research team developed an algorithm using the three lasers to estimate these fabrication uncertainties within a calibration process before performing actual measurements. Furthermore, the problem of determining the deflection of the pavement using the distance measurements generated by the lasers is, however, ill-posed (rank deficient matrix), unless a measurement of the orientation of the beam is available. Thus, the rotation of the beam around its center can be generated by the high-precision RLG, which precisely tracks the orientation of the beam with respect to fixed starting reference.

**Research Performed by:**
Center for Transportation Research

**Research Supervisor:**
Dr. Jorge Prozzi, CTR

**Researchers:**
Joaquin B. Hernandez
Suyash Vishnoi
Christian Claudel

**Project Completed:**
08-31-2019

After the selection of the beam and the laser distance sensors, the deflection measurement system was developed through several steps:

- Deflection estimation by correlation of measurement.
- Deflection estimation using computer vision techniques for matching.
- Implementation of the gyroscope to measure the orientation of the beam.
- Frequency analysis to demonstrate that the sensors do not have any internal vibrations.
- Development of an acquisition interface for better data filtering and synchronization.
- Installation of a third laser in the undeflected outside the deflected area.
- Development of an algorithm to estimate the translational movement of the beam.
- Modification of the beam to ensure alignment of the laser and the gyroscope.
- Manual measurement of the misalignment due to fabrication uncertainty.
- Development of an algorithm to estimate the misalignment by including a fourth laser.

## What They Found

After developing the system, the research team focused on matching the data generated by the different laser distance sensors. The team investigated several image matching techniques to correlate the data sections generated by the different laser distance sensors. It was determined that accurate matching could be achieved in all scenarios covered by the tests using a matching algorithm. The team also developed an algorithm to account for different external vibrations affecting the beam. They identified the limitations of each prototype through experimental validation, gradually addressing the theoretical and practical problems to achieve the required precision. To date, the main issue to be solved is to ensure the rigid body assumption as the system is mounted onto different vehicles.

## What This Means

Using a combination of laser distance sensors and an RLG, This project developed a laser sensor system capable of capturing pavement deflections under a moving vehicle. The surface deflection can be used to address many of TxDOT's needs, such as:

- Measurement of road condition at the network-level,
- Early indication of pavement deterioration, and
- Input for layer moduli backcalculation.

Therefore, a system that can allow TxDOT to measure surface pavement deflections yields multiple benefits. For example, TxDOT could use this device to determine the condition of the pavement and use this information in Pavement Analyst to better manage the state's highway network and to make better informed maintenance and rehabilitation decisions. This information would directly support the 4-Year Plan. In addition, backcalculated layer moduli could be used to improve pavement rehabilitation design.

### For More Information

**Project Manager:**
Wade Odell, RTI (512) 416-4737

**Research Supervisor:**
Dr. Jorge Prozzi, CTR (512) 471-47711

Technical reports when published are available at **http://library.ctr.utexas.edu.**

Research and Technology Implementation Division
Texas Department of Transportation
125 E. 11th Street
Austin, TX 78701-2483

www.txdot.gov
Keyword: Research