Minnesota Department of Transportation
Digital Test Rolling (Laser System)

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Standard Test Rolling (MnDOT 2111)

Test rolling is used, as a quality assurance test, to ensure that embankment materials are meeting compaction requirements. The standard test rolling system finds yielding areas using a rod attached to a heavily loaded trailer system (see figure 1).

Figure 1. Photos of standard test rolling system.

Background

The current test rolling system has its advantages and disadvantages. The disadvantages include: difficult mobilization (costly to transport to various projects, difficult to transport on soft materials near

the right away), requires Agency inspector monitoring during entire test for marking and reporting of failing areas, it is not a permanent record, tires on existing rollers are difficult to obtain and are beginning to visibly deteriorate, and the deep influence depth is not appropriate for some projects (about 4 ft). Consequently, to address these concerns, the laser test rolling system was developed. This system uses two (2) laser sensors mounted to the tire hubs of the steering axle of a standard dump truck loaded to the maximum allowable load. A GPS unit is mounted to the cab of the truck to allow for collection of x-y coordinates for each laser measurement. This data is sent from the data acquisition system directly to a laptop for storage and analysis. Figure 2 and 3 present photos of this system.

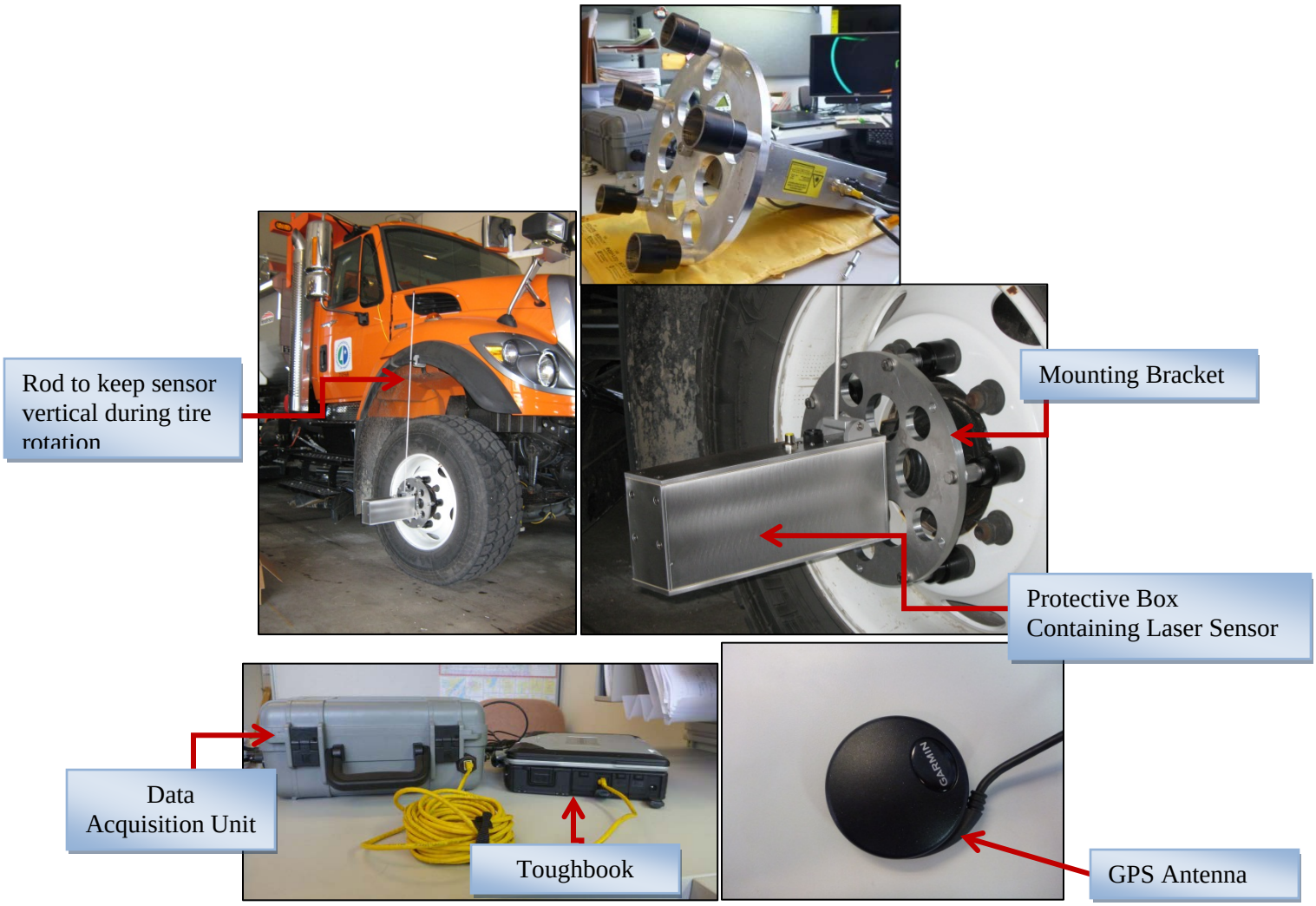

Figure 2. Photos of laser test rolling system.

Figure 3. Field photos of laser test rolling system.

Benefits

- Commercial, tandem trucks are readily available.
- Measurements are:
  - Continuous
  - Digital
  - Spatial
  - Permanent
- Allows for direct correlation to:
  - Other construction activities.
  - Pavement performance data.
  - Intelligent compaction data.
  - Spot testing.
- Near real-time measurements.
- Large coverage.
- Shallower influence depth than standard test rolling. (Approximately 18 to 24 inches for granular material). Therefore, the system can be used on bases and over given sections with utilities – depending upon the design.

- System is portable from one truck to next. Eliminates mobilization costs associated with hauling standard test rolling equipment to site and maneuvering on grade.
- Eliminates need of Agency personnel following behind standard test roller to mark failed locations.
- In the future, this device may be made adaptable for connection to the standard test roller for instances where this is the preferred methodology.

Current Short Comings

- Shallower influence depth than standard test rolling.
    - Stiffness in the top 2 to 3 meters (3 to 6 ft) of embankment materials is important in pavement design. Consequently, the 4-ft influence depth, resulting from the standard test roller test, captures the majority of the critical layer thickness.

      Less weight is allowed on a tandem axle, and therefore, the influence depth of the laser test roller is less. It is anticipated that, in the future Laser Test Rolling specifications, Mn/DOT would require 2 coverages (passes) using the laser test rolling (0 and 2 ft below grading grade) for projects where the top 4 ft of fill require testing. For evaluation of bases, only one coverage using the laser test rolling system would be required at the surface of the base.

Installation Time

- It takes approximately 15 minutes to install the Laser Test Rolling System to the truck. The system must be installed at the job site, as it cannot be attached to a vehicle operating at speeds exceeding 20 mph.

Proposed Use of System during 2013-2014

- Beta test the Laser Test Rolling System, as it is a newly manufactured device, and determine how/whether it can be implemented in the future.
- Digital data collected will be for <u>information purposes only</u>.
- Laser system will be installed onto an Agency truck.
    - Truck will be fully loaded with sand.
    - The snow plow will be attached to provide additional weight to the steer axle.
    - An Agency employee will operate the truck.
- The Laser system should be run prior to standard test rolling, when test rolling is required.

- The system can be implemented on bases and at grading grade. Locations to be determined after further discussions.

Construction Season 2013

The laser system was working well during the 2013 construction season. Deflection measurements from the laser system were matching well with visual operations of quality compaction (i.e., walking along the truck looking for both permanent and plastic deformations). Additional, pilot projects are needed to provide further validation of the system before inclusion into a contract.

Figure 4 – 6 present maps of data collected on some pilot projects.

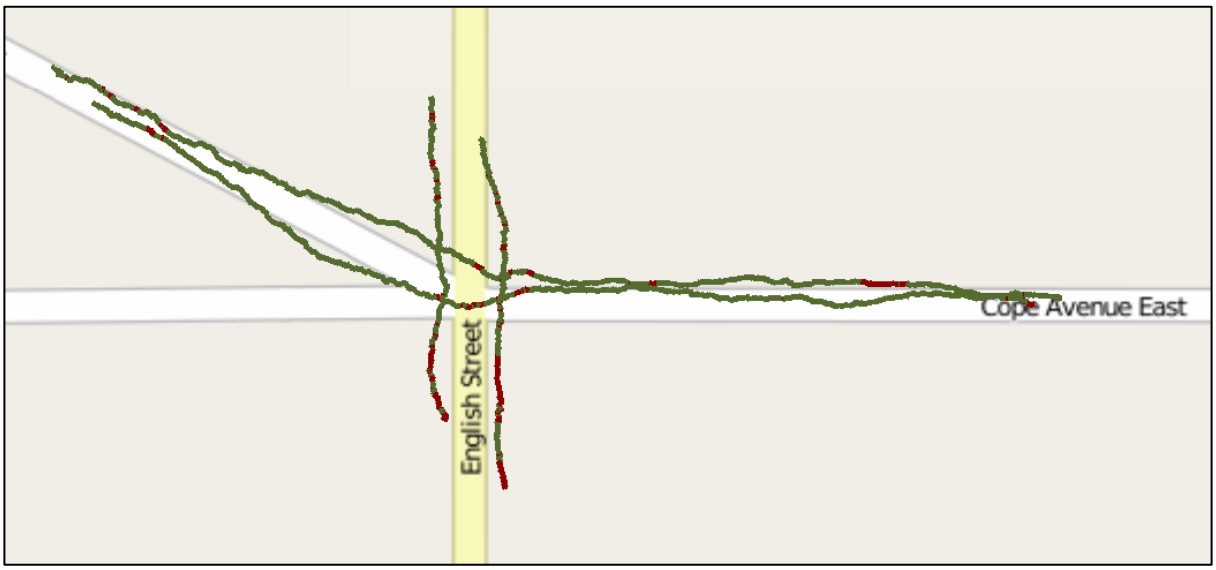

Figure 4. Map of yielding/failing (red) and non-yielding/passing (green) areas on city street application.

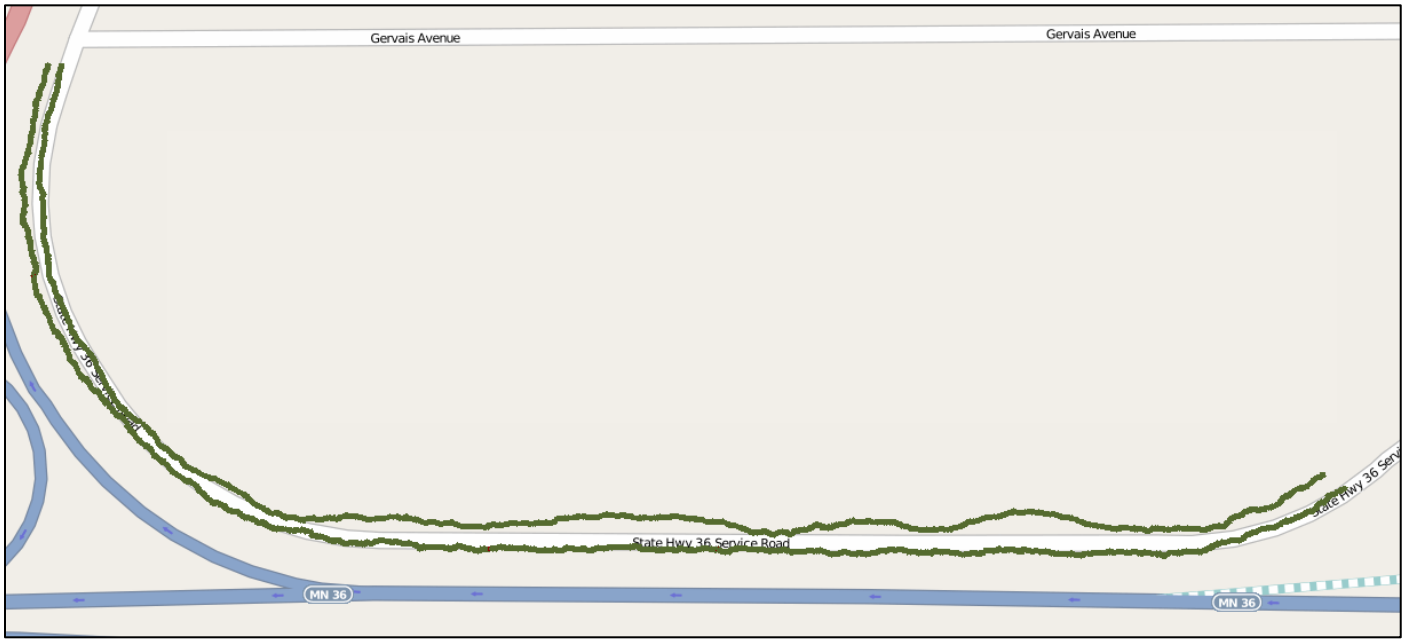

Figure 5. Map of city street that passed digital test rolling along 100% of the length.

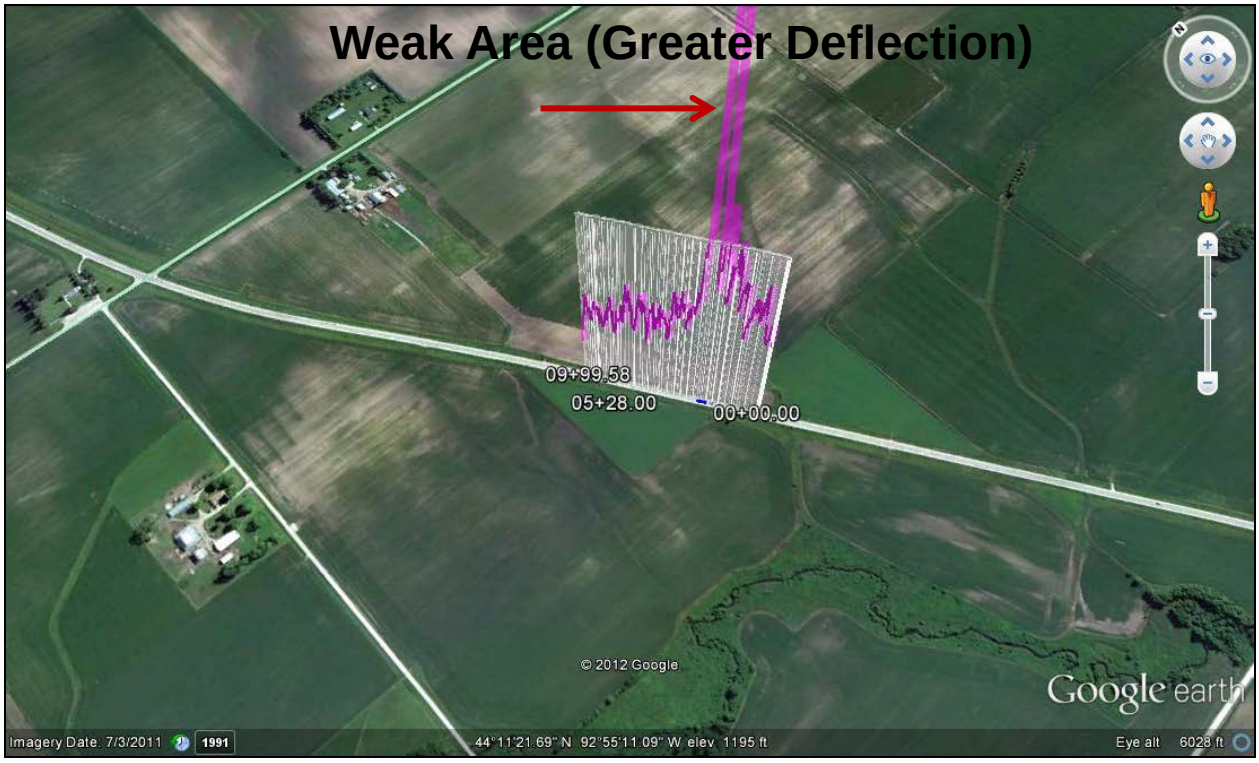

Figure 6. Example of laser measurement data using 2D graph.

Sonic Test Rolling System (original demo system)

A sonic test rolling system (see figure 7) was previously developed under investigation LRRB 2011-15. While this system showed potential promise, there was limited assistance for product development and

enhancements from the vendor. Additionally, there were enherent problems with mounting the sonic sensors directly to the axle beneath the truck (i.e., difficult installation due to limited clearance in the field, sensors also became barried during failures,etc.) Consequently, we solicited participation from other vendors and moved forward with the laser system used during pavement smoothness testing (MnDOT 2399)

Figure 7. Previous digital test rolling system (sonic system).

Past Research Projects

Development of New Test Roller Equipment and Construction Specifications for Subgrade Compaction Acceptance
Author(s): Aaron Budge and James Wilde
Report Date: June 1, 2011
Report Number: 2011-15
Report/Product: http://www.lrrb.org/media/reports/201115.pdf
Abstract:
The current test rolling program as used by Mn/DOT is in need of an update and/or supplement to existing equipment, procedures and specifications. The traditional roller is very heavy and cumbersome and the current construction specification is not technically based. Due to the heavy weight, the roller is only appropriate in approving lifts that are three to four feet thick. While this is ideal for large projects where thick lifts are to be evaluated, most projects do not need this magnitude of loading. This implementation project has developed a more adaptable test roller system and an appropriate construction specification for this modified system. The new test roller and construction specification allow for variation in the weight applied, which will allow varying site conditions to be tested. Such a system

would be especially appropriate for roadways that are designed for less than 10 ton loads. This system is easily transported, such that mobilization will be more efficient, and data are continuously recorded during test rolling. The modified test roller is an instrumented system mounted on a standard dump truck. A new test specification has been proposed for the new system and deflection criteria have been established for several combinations of subgrade types and roller weights. The results of the project have also provided a method for comparing pavement structures and layer properties as constructed to their intended design, linking roller deflections to pavement performance. The new system has been utilized on several regional projects and has been shown to work effectively.

Developing Improved Test Rolling Methods for Roadway Embankment Construction.
Author(s):
Report Date: November 2008
Report Number: 200808TS
Report/Product: http://www.lrrb.org/pdf/200808ts.pdf (0.3MB)
Abstract:
As part of an effort to improve test rolling equipment and specifications, investigators used models and simulations to study soil-wheel interaction, and conducted field and laboratory tests to develop theories linking wheel sinkage to soil mechanical properties.

Development of Improved Test Rolling Methods for Roadway Embankment Construction
Author(s): Andrew Drescher
Report Date: February 2008
Report Number: 2008-08
Report/Product: http://www.lrrb.org/pdf/200808.pdf (7MB)
Abstract:
Test rolling is a quality assurance test in which penetration of the wheels of a heavy vehicle into subgrade soils is used as a measure of the adequacy of compaction. Current criteria for acceptable test roller penetration are empirical. Two theoretical approaches for modeling test rolling are developed. One is analytic and the other is numerical, based on the finite element code ABAQUS. Both approaches relate wheel penetration to wheel geometry, wheel load, and soil strength parameters (friction angle and cohesion). Elastic soil properties are included in the numerical simulations but play a secondary role. The models accommodate both rigid and flexible wheels. Homogeneous and layered soil structures are considered. Scaled laboratory tests support the theoretical predictions, although full validation requires execution of extensive full scale field testing. The models developed can be used to enhance interpretation of test rolling data and assess the effects of test roller modifications.