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Innovation, Research & Implementation Section
Executive Summary Report

Verification of Rut Depth Collected with the INO Laser Rut Measurement System

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Problem

Since 1985, ODOT has been manually collecting rut depth data using a straight edge and dial gauge (S&G). This method is slow and dangerous to pavement condition raters when traffic control is not available. According to the Pavement Condition Rating (PCR) procedures, the rating team is instructed to stop at 1 mile intervals along the predetermined roadway section and evaluate a 100 ft (30.5 m) section of pavement. While this method may be sufficient in many cases, there is potential for raters to overlook short sections of deeper than typical rutting. Also, there have been numerous instances, according to ODOT Infrastructure Management workers, when the level of traffic prevented them from obtaining the necessary number of rut depth measurements to properly evaluate a pavement section. To solve this problem, ODOT purchased two inertial road profilers; one from Pathway Services and one from Dynatest. Both vehicles use rear-mounted INO Laser Rut Measurement Systems (LRMS). These systems utilize two 3D laser profilers and allow the collection of transverse road profiles and calculation of rut depth measurements while the vehicle is in motion, even at high speeds. With the LRMS, numerous rut measurements can be obtained at short intervals over the entire section in a much shorter period of time. The safety risk for the rating team is greatly reduced because they can obtain measurements without leaving the vehicle and without interfering with traffic flow.

As previously discussed, manual evaluations of rutting for the PCR are often based on few actual measurements because of traffic and time limitations. ODOT has collected a database of PCR ratings for rut depth based on manual measurements, LRMS data, or both. The two methods of evaluating rut depth may produce significantly different PCR scores for the same section of pavement. A method for reconciling the difference between the two methods is needed. Before this can be done however, the accuracy, precision, and repeatability of the LRMS system needs to be confirmed.

During the initial preparation for this project, it was discovered that the straight edge and dial gage being used by the ODOT technicians was only 4 ft (1.22 m) in length.

The ASTM standard for rut depth measurement (ASTM E 1703/E 1703M, 1995) specifies a minimum length of

1.73 m (5.67 ft) and recommends a length of 1.83 m (6 ft), 2 m (6.56 ft), 3 m (9.84 ft), 3.05 m (10 ft), or 3.66 m (12 ft). Not only is the ODOT straight edge limited by length, but the dial gage is fixed at the center of the bar. It is necessary to determine the possible effect of these factors on the rut depth measurements gathered by ODOT pavement raters.

Objectives

The main goals of this study were to evaluate the rut depth measurement collection techniques used by ODOT and to verify data gathered using the automated laser rut measurement system. To meet these goals, the following objectives were devised and met:

- Conduct tests on a section of rutted pavement at one or more locations using the LRMS, straight edges, and profilometer
    - Evaluate the LRMS data for precision, accuracy, and repeatability using the S&G method and Ohio Research Institute for Transportation and the Environment (ORITE) profilometer as references
    - Examine the potential effect of straight edge length on the accuracy of S&G measurements to determine whether the 4ft straight edge used by ODOT is adequate
- Develop a method for extracting rutting distress scores from the LRMS data to be used with the ODOT pavement condition rating system
- Recommend other parameters (maximum, minimum, etc.) that may be suggested by the data for the use and interpretation of INO rut depth measurements

Description

In order to verify the results of the LRMS system, two 200-ft (60.96 m) sections of pavement with rutting at a variety of severity levels were selected for data collection and study. Each 200-ft (60.96 m) section was measured and marked at 5 ft (1.52 m) intervals. At each interval, rut depth was measured in both the left and right wheel paths using the profilometer, 8 ft S&G, and 4 ft S&G. Workers from the ODOT Infrastructure Management division made five runs at each site with the Dynatest profiling vehicle over a greater length of pavement that contained each 200-ft (60.96 m) section. As the vehicle approached the test sections, the system was switched to rapid-fire mode in order to provide a greater number of measurements for analysis

A site was selected on US-30 near Wooster, Ohio for testing. The 200-ft (60.96 m) section was in the westbound approach to a stoplight at the intersection of US-30 and SR-94. This area receives a significant amount of large truck traffic. The stopped or slow-moving, heavily loaded trucks had produced a section of extremely severe rutting and upheaving. Areas away from the intersection were typically characterized by light or medium rutting.

A second test site having a more typical section of distressed pavement was needed in order to evaluate the LRMS system under normal conditions. A section of SR-682 in Athens County, Ohio was chosen for its low to medium severity rutting. This section is similar to the pavement sections typically found in the PCR database.

The LRMS data collected at both sites was analyzed and compared with the measurements taken using the ORITE profilometer and the S&G methods. Statistical analyses were conducted using ANOVA and Games-Howell tests. First, the LRMS data was studied alone to assess repeatability and accuracy of the system. Then, the LRMS data were analyzed along with the profiler and S&G measurements using the same tests to evaluate the system for precision.

The PCR ratings for rutting based on S&G measurements were compared to data collected in ODOT District 10 using the INO LRMS system on the Dynatest profiler. There were 397 locations found for which there exists a PCR score based on manual measurements as well as LRMS data. The following Ohio counties were represented in the data: Athens, Gallia, Hocking, Meigs, Monroe, Morgan, Noble, Vinton, and Washington.

The data files were imported into Microsoft Excel and separated into the necessary log point intervals to correspond with the S&G data. Each interval was assigned a PCR score based on rut depth and extent according to the key and rating form.

Extraction of the PCR scores was done in Excel, using a spreadsheet that was pre-made to allow one to simply paste the data from the files created by the Dynatest software. To do this, each file (extension ".HDR") was imported as a comma-delimited data set. The rows were sorted so the relevant data could be isolated and copied into the pre-made spreadsheet. The spreadsheet then counted the number of rut depth measurements that fell into each severity category and multiplied each of these counts by the measurement interval. These three numbers were divided by the overall length to find the extent of rutting in each severity category.

Results and Conclusions

This study was conducted to assess the performance of the laser system and develop a method for extracting PCR scores from rut depth data gathered with the LRMS. The Laser Rut Measurement System provides the Ohio Department of Transportation with a valuable tool for evaluating the condition of pavement infrastructure. The high density of measurements and the accuracy of the laser system allow for a much higher quality assessment of rutting distresses than the traditional manual measurement methods. The ODOT profiler vehicles also allow pavement raters to evaluate a pavement segment in a much shorter amount of time and in a safer manner. Manual measurement requires the pavement rater to be exposed to the hazards of traffic. The ODOT profiler vehicle has the ability to operate while moving with the flow of traffic, thereby dramatically reducing risk of injury. The effect of the length of the straight edge used for manual measurements was also examined.

To test the system's performance, two tests were conducted on selected pavement sections. The first test was performed on a west-bound section of US-30 in Wayne County, Ohio. This section is heavily used and had undergone light rutting over most of its length, with the exception of a severely rutted 200-ft (60.96 m) section at the approach to its intersection with SR-94. This section of severe rutting was also measured using the profilometer, 8 ft straight edge, and 4 ft straight edge. ODOT provided LRMS data from five runs made with the profiler vehicle over a section approximately 1.53 mi (2.46 km) in length that included the 200-ft (60.96 m) test section. The second test was over a lightly used section of SR-682 in Athens County, Ohio. This segment of SR-682 had undergone low-to-medium rutting over its entire length. A 200-ft (60.96 m) section was selected and rut depth was measured using each of the four methods. Again, ODOT provided LRMS data from five runs over a section approximately 0.80 mi (1.29 km) in length that included the 200-ft (60.96 m) test section.

Statistical analyses were conducted on the data gathered from the two tests using ANOVA tests and Games-Howell post-hoc tests. The results of only the LRMS were examined for accuracy and repeatability, since the other methods were presumed accurate. The statistical analysis of the data from US-30 showed weak statistical similarity when the entire length of profiled pavement was considered. When only the 200-ft (60.96 m) test section was considered, strong statistical similarity was found. When the data from SR-682 was analyzed, statistical similarity between runs was found for the the entire pavement length as well as the 200-ft (60.96 m) test section at this site. The mean absolute deviations for the tests at SR-30 and SR-682 were 0.026 inches (0.660 mm) and 0.030 inches (0.762 mm) respectively. The distributions of measurements by PCR severity level over the entire pavement lengths show that the LRMS system is capable of producing the consistent and reliable PCR scores. Given that these tests were run under somewhat uncontrolled field conditions, it is believed that the results of these tests and analyses are evidence enough to conclude that the LRMS system produces repeatable and accurate results.

Rut depth data from the LRMS, profilometer, 8-ft S&G, and 4-ft S&G for the 200-ft (60.96 m) test sections were analyzed and compared using the ANOVA and Games-Howell tests to assess the precision of the LRMS system and to examine the impact of the shorter straight edge on rut depth measurements. With the exception of the left wheel path data from the profilometer on SR-682, the LRMS measurements at both sites strongly correlated with the profilometer and 8-ft S&G. The profilometer data from SR-682 were influenced by deterioration in the left wheel path that caused the rut depth algorithm to interpret pits in the pavement surface as the bottom of the rut. These data were considered invalid and were disregarded. The strong statistical similarity found in the results of the ANOVA and Games-Howell tests indicate that the LRMS produces accurate rut depth measurements. The 4-ft S&G however did not show strong similarity to the other measurement methods. The shorter length did not allow the straight edge to fully span the width of the rut in many cases. To prevent error and inaccuracy, the 4-ft S&G should be replaced with a device that meets the criteria listed in ASTM E 1703/E 1703M.

Recommendations

The LRMS displayed sufficient precision, accuracy, and repeatability in this study and is capable of producing reliable information for pavement evaluation purposes. To ensure that the system continues to operate properly, regular checks should be conducted. It is recommended that a section of light-use, low-traffic pavement with a range of rutting distress be selected for checks. The profiler vehicle should be run on this section monthly to ensure that readings are unchanging. More frequent checks may be necessary if the profiler is undergoing heavy use. Checks conducted less frequently may be misleading due to changes in the pavement surface caused by environment or its continued use.

PCR scores can be extracted from the Dynatest .HDR files using the method described in Section 4.1. To prevent small, isolated areas of heavier rutting from mischaracterizing the pavement section, a range of 5-25% is suggested for the “occasional” extent classification. These isolated areas that would not account for 5% or more of the section length should still be reported and considered when performing rehabilitation. The presence of isolated and localized sections of severe rutting is represented in the extent values calculated during the analysis of the rutting files.

Throughout the LRMS data gathered at both sites, there are short sections where one of the five runs produces significantly lower rut depth values than the others. It is suspected that this was a result of the profiler vehicle wandering laterally. Further study may be needed to determine the extent to which this may affect results. It is important that the LRMS operators attempt to keep the vehicle traveling within the existing wheel paths to improve the likelihood of consistent results.

Above: Measuring rut depth with straight edge and dial gauge.
Below: INO Laser Rut Measurement System mounted on Dynatest profiler vehicle.