

CHAPTER 8: FRICTION METER

Pavement surface friction is a critical factor in keeping moving vehicles under control. The study team recognized the benefits of incorporating a friction-measuring device on the prototype vehicles to help operators make decisions about applying materials to keep surface friction at a safe level. A friction testing device and procedure used by most states to measure warm pavement friction values—the ASTM E-274 skid trailer—is not used in the winter because it requires a spray of water in front of the tire, which is not feasible when temperatures are below freezing. However, one manufacturer of friction measuring devices, Norsemeter AS of Oslo, Norway, and its agent Roadware Corporation of Paris, Ontario, Canada, agreed to participate in the study and provide three Roadway Analyzer and Recorder (ROAR) friction meters for testing on the prototype winter maintenance vehicles.

The ROAR friction meter has been tested successfully on airport runways as part of a multiyear winter friction project sponsored by NASA, FAA, and Transport Canada. The units are also being used by several Scandinavian road authorities to test highway conditions, with the goal of establishing monitoring systems that can be used to advise the public of winter road conditions. In 1995, the Minnesota DOT conducted tests in the Minneapolis area using a ROAR prototype, and the results indicated that such devices held promise for determining the friction condition of snow-, ice-, and slush-covered pavements.

Installing and operating the ROAR meters on the prototype vehicles provided some installation and operational challenges. This chapter discusses the ROAR meter, installation procedures, operations and test sites, data analysis, and lessons learned during Phase II.

OBJECTIVE

Conduct proof of concept regarding incorporating friction-measuring devices on winter maintenance vehicles to measure pavement surface friction.

MEASUREMENT

The ROAR friction meter is installed on prototype maintenance vehicle. Expected performance includes the following: First, friction data collected by the prototype vehicle under controlled wet/dry conditions are reasonable when compared favorably with data collected by a ROAR friction meter on a Roadway trailer and by ASTM E-274 (American Society of Testing and Materials) skid trailers; that is, when the data are plotted, they have similar slopes. Second, friction data collected by the prototype vehicle during normal winter maintenance operations are reasonable.

DISCUSSION

The ROAR friction meter basic unit employs a hydraulic mechanism to apply a braking force to an ASTM E-1551 test tire with a 400 mm (15.75 in) diameter pneumatic tire that rides on the roadway. The ROAR consists of the basic friction measuring unit, two electronics enclosures, and an operator panel. The exterior measurements are approximately 36 inches high by 18 inches wide by 31 inches long. The basic unit has a total weight of approximately 330 pounds, including brackets and other mounting hardware. The ROAR friction analyzer is controlled by electronics in a weatherproof master control enclosure. A second enclosure containing an IBM compatible computer is installed in the operator cab. A color LCD operator panel is also mounted in the cab. During Phase II, the ROAR operating functions were incorporated into the PlowMaster display, and the ROAR display panel removed from the cabs.) The equipment operates at travel speeds from 10 to 130 kilometers per hour. ROAR measures friction when the road surface is bare and dry, as well as when it is contaminated by water, snow, slush, or ice. From a winter road maintenance perspective, contaminated road surfaces are the primary interest, and ROAR is specifically designed to operate reliably under harsh winter conditions.



During operation, the hydraulic flow is metered to cycle between free-rolling and locked wheel at preselected intervals. During Phase II, the cycle time was usually set at two- or four-second intervals. In calibrating the friction meter, the three state DOTs simulated the skid number (SN) of the ASTM test standard E-274 using the International Friction Index (IFI) standard ASTM E-1960.

Figure 8-1 ROAR Friction Meter

The ROAR friction meter has two substantially different measuring modes. In Continuous Friction Measurement Equipment (CFME) mode, the tire is slipped at a constant percentage of the forward speed. In this measuring mode, the friction meter supersedes the old fixed slip measuring devices by offering the equipment operator the option of setting the constant slip ratio of the measuring wheel to any percentage between five percent and 100 percent. The setting most commonly used is around 18 percent.

The second measuring mode, variable slip mode (% slip), is becoming the new industry standard. According to Norsemeter, friction outputs in the variable slip mode agree with outputs from decelerometer measuring devices on winter contaminated roads, providing consistent comparisons between the ROAR friction meter and other more conventional friction measuring devices such as the ASTM E-274 trailer. In the variable slip mode, the ROAR meter measures the friction of the road surface by computer controlled braking of the test wheel from free-rolling to fully locked, while constantly monitoring the braking friction force that the road

surface exerts against the test wheel. The test wheel is hydraulically braked under computer control over a 0.5-second interval. During this time several hundred friction readings are recorded and various parameters such as peak friction are calculated. The wheel is then given time to come back up to full vehicle speed before starting another measurement. The time interval for each measurement cycle is set by the operator and in this test was typically two to four seconds between readings. At 30 miles per hour, a vehicle travels 44 feet per second. This results in a friction measurement over an 11-foot portion of an 88-foot segment when the test cycle time is set at two-second intervals. (Refer to Appendix E for additional details.) The friction meter provides measures of friction for clean and bare road surfaces, as well as for surfaces contaminated by water, snow, slush, abrasives, or ice.

During winter maintenance operations, road authorities typically use the variable slip mode, and this was the mode used during Phase II proof of concept for the friction meter.

Installation

Normally, for summer friction measurements, the ROAR friction meter is mounted on a trailer equipped with a water tank and metering system. The friction meter's design also allows mounting on the back of a one-ton pickup truck or other large vehicle when water is not necessary or desirable, as in winter operations. The study team was aware that successfully mounting the friction meter on a snowplow might be challenging because of tight space restrictions and the harsh environment it would encounter.

As expected, one of the first obstacles to installation was finding a suitable space in which to mount the ROAR device. It measures 36 inches tall by 18 inches wide by 31 inches long, and weighs approximately 330 pounds. In addition, it requires seven inches of vertical clearance to raise and lower the unit.

On Iowa's vehicle, the ROAR friction meter was installed in front of the left dual rear wheels, just behind the underbody plow. This location restricted the underbody plow to one angle (to the right; interference problems would occur if the underbody blade were angled to the left). While not wholly desirable, this location was considered acceptable for proof of concept in Iowa. Iowa's ROAR unit experienced two malfunctions. In one case, the axle on the test tire wheel broke. Heavy damage to the tire itself indicated the wheel hit a pothole or other obstruction when the wheel was locked in the down position, putting excessive strain on the axle shaft and sheering it off internally. A new axle was installed and no further problems with it were noted. The other malfunction was traced to a ROAR computer program. Data could not be removed from the computer's main memory because the operators inadvertently shut off the computer system before completing a normal shutdown procedure. A software fix was developed by Norsemeter and installed by Roadware to avoid this problem in the future. (The same situation was discovered in the other ROAR systems, and Roadware installed the software fixes.)

On Minnesota's vehicle, the ROAR friction meter was installed behind the right dual rear wheels because Minnesota DOT did not want to limit the use of the underbody blade, especially for clearing left lanes of multilane highways. However, this location caused mounting problems. Special brackets were fabricated by Tyler (the technology integrator) to mount the ROAR

friction meter's computer relay control between the frame rails of the vehicle. After the initial testing in September 1997, Minnesota DOT mechanics redesigned the mounting bracket because it was cracked and twisted, reinforcing the lower arm of the mount and straightening it to allow the ROAR unit to raise and lower properly. Minnesota DOT also moved the box mounted in the frame rails to the rear of the prototype truck because of its previous relative inaccessibility during repairs. Because of its location at the rear of the vehicle, the ROAR unit installed on the Minnesota DOT's prototype vehicle was subjected to salt and sand dispensed from the center-mounted spreader spinner. A metal plate on the discharge chute was installed to reduce the amount of material actually hitting the unit. However, the swirling air behind the truck still caused some material to hit the ROAR unit. A much more critical problem was the serious whipping and bouncing to which the ROAR unit was subjected at the back of the truck, resulting in several belt failures caused by a bent measuring wheel axle. In one case, the actuator to raise and lower the unit broke a mounting lug. Investigation showed this was also caused by the violent bouncing motion of the ROAR unit at the back of the truck. To correct this problem, Norsemeter designed and shipped a heavy-duty hydraulic damper (shock absorber) assembly that each of the three DOTs installed on their ROAR friction meters. The shock absorber eliminated the bouncing, and no failures were encountered after installation of the shock absorbers.

The Michigan prototype vehicle had no room either in front of or behind the real dual wheels. After lengthy discussions, the Michigan ROAR meter was mounted on a separate pickup-class truck that had been used to tow an E-274 skid trailer for summer friction operations. This produced an excellent environment, and no difficulties were encountered with the installation or operation of Michigan's ROAR unit. However, because it was mounted on a separate vehicle, the ROAR unit could not be interfaced with the Rockwell PlowMaster.

While not officially a part of this study, a fourth ROAR friction meter was mounted Minnesota DOT on a snowplow in the Duluth, Minnesota, district on a 50,000-pound GVW snowplow without an underbody blade. The installation and operation of this unit went smoothly, and it was used for part of a Federal Highway Administration comparison of winter friction devices, independent of this study.

After much effort in all three states, then, the friction meter was securely and relatively satisfactorily installed only on Iowa's prototype vehicle, passing the installation proof of concept. Even after significant fabrication, Minnesota's friction meter installation was only marginally satisfactory on the prototype vehicle, although it was completely satisfactory on the Duluth vehicle without an underbody blade. In Minnesota, therefore, installation feasibility was only marginally proved. A friction-measuring device was not installed on Michigan's prototype vehicle. Electronic connection between the friction meter and the onboard PlowMaster was proved feasible in Iowa and Minnesota.

See Figures 8-2 and 8-3 for the Iowa vehicle friction meter location.



Figure 8-2 Friction meter, Iowa prototype vehicle



Figure 8-3 Friction meter, Iowa prototype vehicle

Operations

Roadware representatives conducted training sessions for operators of all four ROAR units. While these training sessions were adequate, the operators' skill levels deteriorated during the course of Phase II, causing some operator errors in operating and recording friction data during winter storms. This was judged to be a result of the fact that the ROAR friction meter is designed to be operated by more highly trained technicians accustomed to working with complex testing systems. This conclusion was borne out by the fact that the Michigan DOT operator, who was normally assigned to operate the ASTM E-274 skid trailer, had fewer operator errors and no operating difficulties.

Performance under Dry/Wet Conditions

Dr. James Wambold at CDRM, Inc., suggested that the data collected by the onboard friction meters could be proved reasonable (i.e., proof of concept for friction meter performance) by comparing the data to an industry standard. The following sections discuss the calculation of friction coefficients and the correlation of collected data to ASTM E-274 skid trailer base data.

Friction Coefficients

When measuring friction, the critical value is μ_{peak} or the point at which slipping will occur. Equation 1 demonstrates how μ_{peak} is obtained, based on the Rado friction model. See Appendix D for a complete description of the Rado model included in *A Primer on Modern Runway Surface Friction Measurement*.¹

$$\mu(S) = \mu_{\text{max}}(S) \cdot e^{-[\ln(S/S_{\text{max}}) + C]^2}$$

where μ = friction number

$\mu_{\text{max}} = \mu_{\text{peak}}$

S_{max} = critical slip (slip speed at which μ_{peak} occurs), also called *Scrit*

S = slip speed (% slip times vehicle speed)

C = shape factor

V = vehicle speed

The variable slip measuring cycle can be applied repeatedly in a pulsing measuring manner, so as to determine the friction equation for surface segments from 3 to 30 meters in length depending on the traveling speed of the measuring device. When a segment is not sufficiently homogeneous for the quality of the curve fitting, the measurement will be discarded manually.

The friction meter reads several values of μ , C , S , and S_{max} over a short period of time and obtains the μ_{peak} value shown in the sensor output. As shown in Figure 8-4, the factor C mainly affects the shape of the curve. A low value of C produces a curve with a steep slope (a large speed gradient); whereas, the larger C is, the less speed dependent. The uppermost value on the curve is the μ_{peak} value. The slope of the curve beyond the μ_{peak} value depends on the macro texture of the pavement (C^2); i.e., a flatter slope beyond the peak represents a more acceptable pavement friction value.

¹ Norsemeter AS *A Primer on Modern Runway Surface Friction Measurement* Courtesy Publication 2, Chapter 3, page 8. Rud Norway 1996

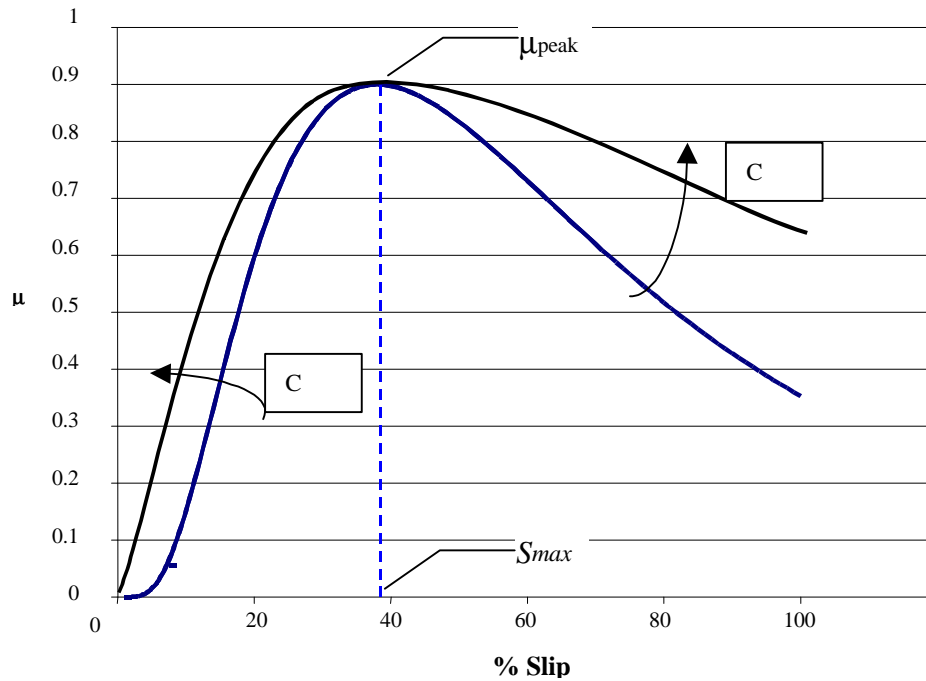


Figure 8-4 Rado Model friction print

Correlation Testing

To check the reasonableness of data collected by the ROAR friction meters on the prototype vehicles, data collected by the ROAR friction meters were compared to ASTM E-274 skid trailer base values, the U.S. industry standard for pavement friction measurements. If plotted data collected by ROAR friction meters (on the prototype vehicles and on Roadware’s trailer) have a similar slope to base data collected by the ASTM E-274 trailer, the ROAR data should be reasonable. Testing to correlate the data was completed on September 18, 1997. A test track in St. Cloud, Minnesota, which could be flooded and contained no other traffic, was used. The track had four sections of pavement with average mean texture depth as shown in Table 8-1. Additional track condition information is given in Appendix E.

Table 8-1 Texture of St. Cloud, MN, test track, September 18, 1997

Track Site	Speed Gradient (kilometers/hour)	Mean Texture Depth (MTD)
1	74	.75
2	16.17	.24
3	46.33	.51
4	182.18	1.71

The St. Cloud tests were conducted under both dry and wet pavement conditions at speeds of 20, 30, 40, and 50 mph. The test devices used in this data collection session were the Iowa prototype vehicle equipped with a Roadware ROAR friction meter, the Minnesota prototype vehicle equipped with a ROAR friction meter, a Roadware ROAR friction meter trailer, the Iowa ASTM E-274 skid trailer, and the Minnesota ASTM E-274 skid trailer. Michigan did not participate. The ASTM E-274 skid trailers and Roadware’s trailer recorded friction data while the Iowa and Minnesota prototype vehicles followed directly behind and recorded friction data with the ROAR friction meters. During the St. Cloud tests, the ASTM E-274 trailers traveled at a designated speed, water was dispersed on the pavement at a specified depth ahead of the tire, and the braking system systematically locked the test tire while the resulting friction force between the tire and the pavement was recorded. A water truck was used to disperse water directly ahead of the prototype vehicles.

ASTM E-274 skid trailers utilize the ASTM E-274 Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire. The E-274 trailer traveled at a designated speed, water was dispersed on the pavement at a specified depth ahead of the tire, and the braking system systematically locked the test tire while the resulting friction force between the tire and pavement was recorded. See Figure 8-5 for a list of ASTM E-274 test parameters.

K.J. Law ASTM E-274 Skid Trailer

- K.J. Law Input/Output Parameters:

 - Time
 - Date
 - Distance
 - mpeak
 - Speed
 - Air Temperature

Figure 8-5 ASTM E-274 parameters

During the St. Cloud data collection sessions, the following data were recorded: skid number (SN) from ASTM E-274, % slip, μ_{peak} friction value, speed of trailer, air temperature, time, and date. Data collected by the ROAR meters on Iowa's and Minnesota's prototype vehicles and on the Roadware trailer, and by the ASTM E-274 skid trailers, were examined by Dr. Wambold to determine the difference of values reported by the ROAR devices on the prototype vehicles, the significance of those differences, and whether the ROAR devices pass proof of concept. For each friction meter in each data run, the % slip at the peak (S_{max}), was plotted at the corresponding vehicle speeds. As shown in Figure 8-6, data collected by the Roadware ROAR skid trailer instrument and the ROAR friction meter on Minnesota's prototype vehicle had similar slopes; data collected by the Iowa prototype vehicle's ROAR friction meter had a flatter slope and showed a different trend.

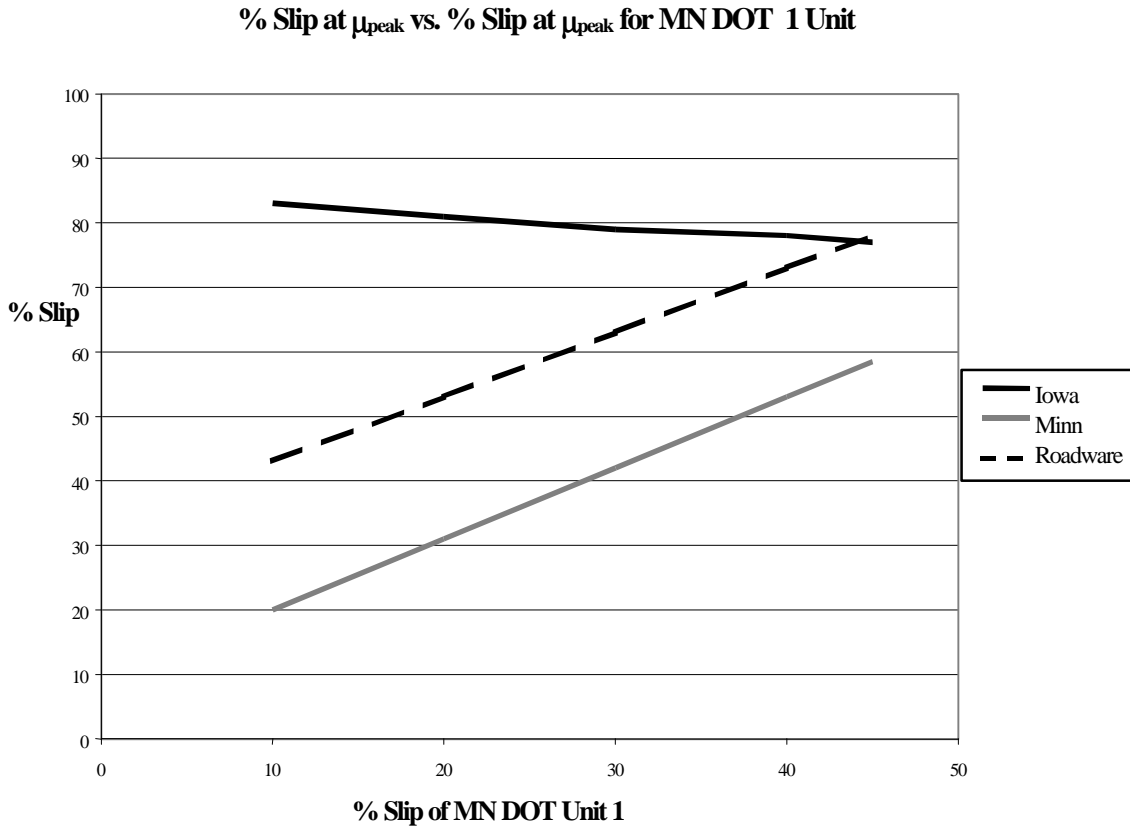


Figure 8-6 Friction trends from data comparison, St. Cloud, Minnesota, September 18, 1997. Figure is courtesy of Dr. James Wambold.

Dr. Wambold found no significant factor contributing to Iowa's skewed data from September 18, 1997. A Roadware representative, however, examined Iowa's raw data and determined that during the test, the Iowa operator had not followed the correct start/stop sequence during the St. Cloud tests, and the data records for the various runs could not be correctly interpreted. A software fix was developed by Norsemeter and installed by Roadware to avoid this operator error in the future.

After the software was installed, additional tests were then conducted with the Iowa prototype vehicle on April 16, 1998, in Iowa. During these tests, the vehicle was equipped with a temporary water dispensing system that directed water in front of the tire. Since only a wet surface was required for testing, the amount of water applied was not calibrated. At higher speeds (50 mph), the test tire chirped frequently, indicating that not enough water was being dispensed for the higher speeds. A larger hose could be used in future testing to ensure that the pavement was wetted properly at higher speeds.

Three test sites were used for the April 16 testing, and runs were repeated at several speeds. These sites were selected from several in the Ames, Iowa, area and were selected to represent different pavement surfaces: old portland cement concrete, new asphalt concrete, and old asphalt concrete. See Appendix F for a map and descriptions of these test site locations, as well as test notes and data.

For each data collection run, the % slip at μ_{peak} was plotted at corresponding vehicle speeds. In Figure 8-7, data from the tests runs (% slip versus vehicle speed) are plotted, showing a slope similar to that derived from data collected by the Minnesota vehicle and the Roadware trailer in St. Cloud on September 18, 1997.

% Slip at μ_{peak} vs. % Slip at μ_{peak} for MN DOT 1 Unit

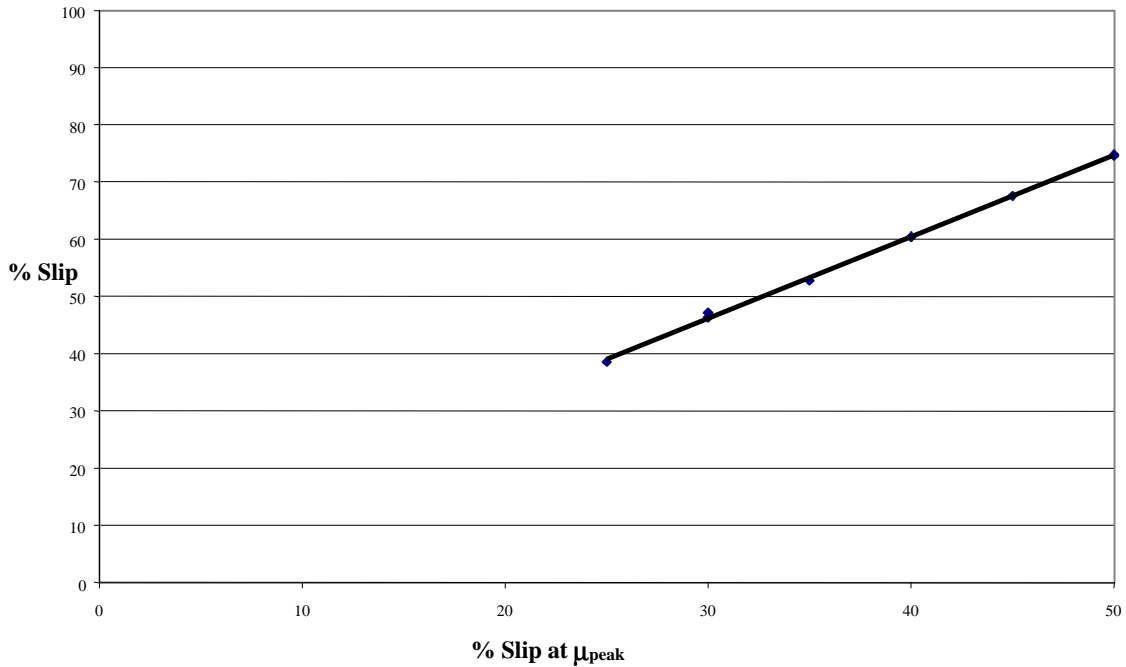


Figure 8-7 Additional Iowa testing results, April 16, 1998

In Figure 8-8, Iowa's April 16, 1998 data slope is superimposed on September 18, 1997 data slope from the Minnesota and Roadware friction meters to show the similarity in slopes. Therefore, the concept is proven that a maintenance vehicle equipped with a friction measuring device can collect reasonable friction data during dry or wet conditions.

% Slip at μ_{peak} vs. % Slip at μ_{peak} for MN DOT Unit 1

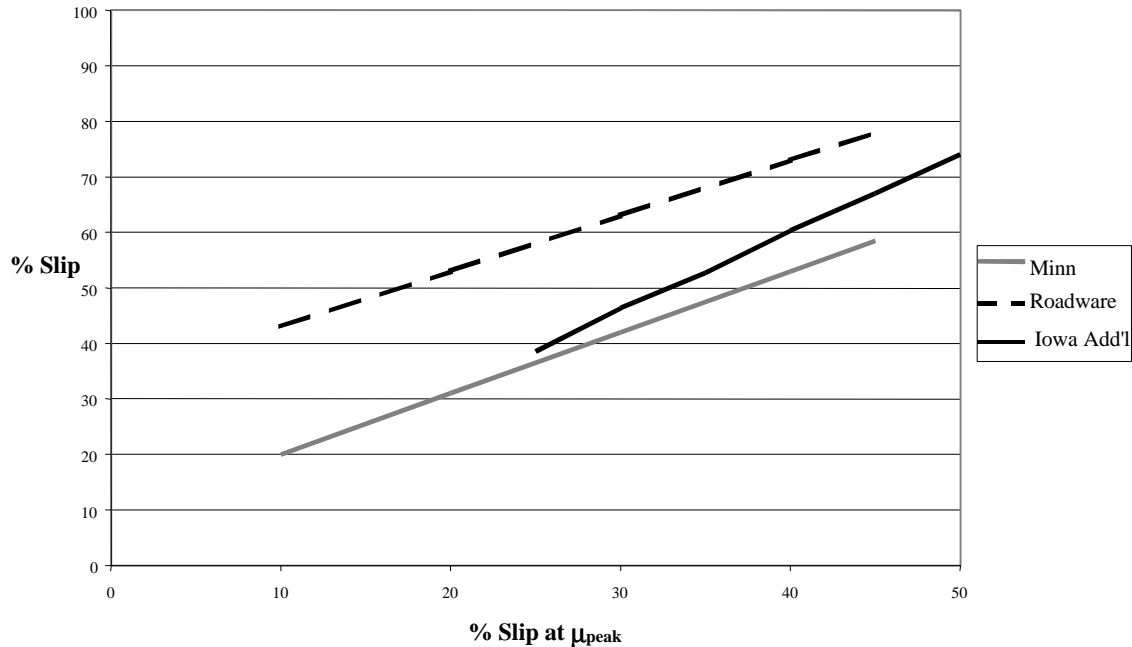


Figure 8-8 Comparison of Iowa’s additional test results from April 16, 1998, with trendlines from Minnesota DOT and Roadware data collected on September 18, 1997, courtesy of Dr. James Wambold

As a final step in the proof of concept, the peak measurements and F60 of the Norsemeter Friction Units are compared to the peak and skid number (SN) values measured with a K.J. Law E274 Unit. Figure 8-9 illustrates the comparisons of the peak value and Figure 8-10 illustrates the comparison of F60 to SN. All of the data are from the September 18, 1997 tests. The Iowa ROAR unit μ_{peak} are compared to the μ_{peak} of the Law units. Dr. James Wambold analyzed these data. He found that the Roadware and Minnesota Law units compared favorably. He further found that while the Iowa μ_{peak} values do not unconditionally agree to the others, the data still sufficiently correlate. Therefore, the concept is proven that a maintenance vehicle equipped with a friction measuring device can collect reasonable friction data during dry or wet conditions.

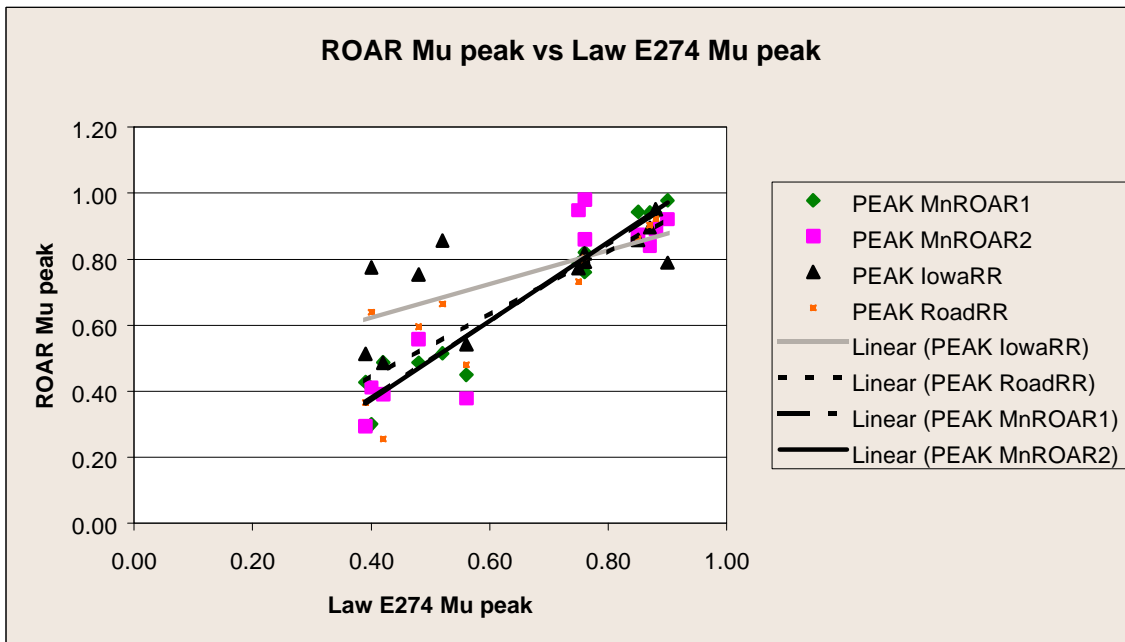


Figure 8-9 Comparison of Mu Peak measured by the various Norsemeter units versus the Mu Peak measured by a K.J. Law Unit at the September 18, 1997 tests. Figure is courtesy of Dr. James Wambold.

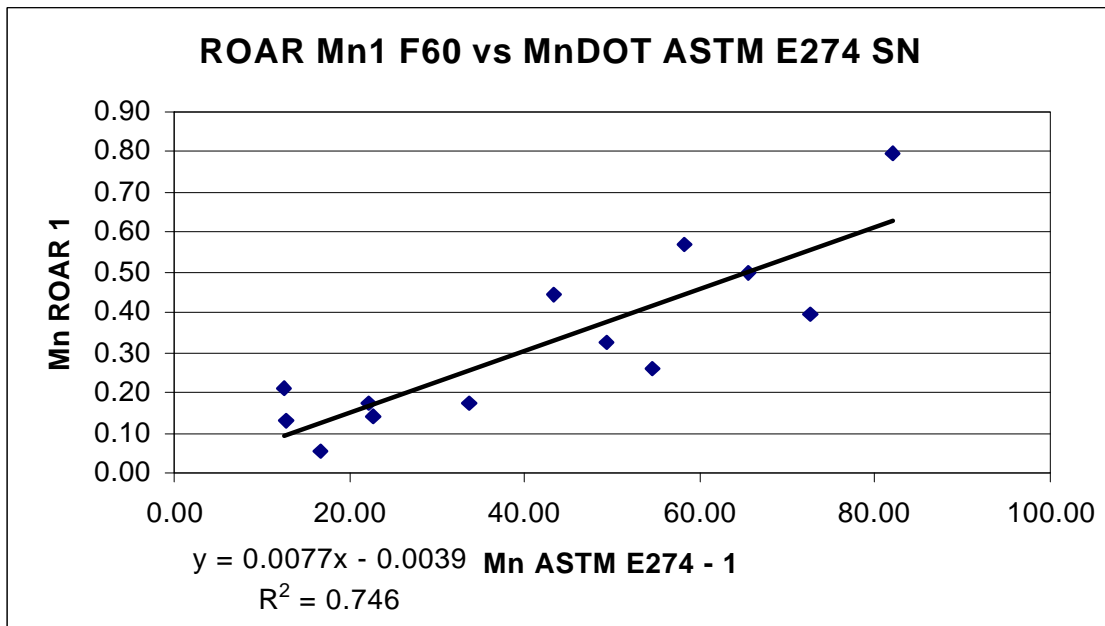


Figure 8-10. Comparison of F60 measured by the various Norsemeter versus the Skid Number (SN) measured by a K.J. Law E274 unit at the September 18, 1997 tests. Figure is courtesy of Dr. James Wambold.

Performance under Winter Conditions

With assurance that, under dry or wet pavement conditions, Iowa's and Minnesota's friction meters were recording and reporting reasonable data, the study team wanted to begin collecting friction values representing a variety of winter conditions to prove the concept under winter conditions. Additional friction data would be important not only to this study but also for another research project in Minnesota. (See Appendix G for the work plan for Test and Evaluation of Friction Measuring Devices for Winter maintenance Activities.) Therefore, CTRE collected some winter data and laid the foundation for full-scale data collection and evaluation in Phase III.

First, the data collection plan in Figure 8-11, based on Minnesota's work plan for the above-named project, was approved by the study team and distributed to the partner states. Significant time was devoted by CTRE staff to developing data conversion macros, as discussed in Chapter 13. These macros provided the tools to quickly translate data collected by the onboard sensors into common formats (e.g., translate latitude/longitude to milepost location, GPS time to Central Standard Time, etc.) and to plot data sets and subsets, including friction data.

Unfortunately, few data sets were collected during the winter of 1997-1998. The weather was atypically warm, with few snow events. Another significant problem was that the collection process was not tightly controlled. Some data sets forwarded to CTRE included incomplete or clearly unreasonable readings that were traced to operator errors. Data were generally received several days or even weeks after they were collected, making it virtually impossible to correlate data collected under similar conditions or, if appropriate, to notify operators their equipment was malfunctioning.

Delays in receiving data were a direct result of the fact that the primary mission of the snowplow operators was snow and ice control; data collection and transfer were secondary. All the operators were genuinely cooperative and enthusiastic; however, they were not under the direct control of the principal investigator. As a result, tight coordination was not possible, and not enough friction data were collected during winter maintenance operations to prove the concept.

OBSERVATIONS

Proof of concept for friction measuring devices on winter maintenance vehicles was only moderately successful. Installation was successful in Iowa and moderately successful in Minnesota; the ROAR meter was not installed on Michigan's prototype vehicle. Performance (the collection of reasonable data) was successful on dry/wet conditions in Minnesota and Iowa but could not be proven for winter conditions due to lack of data.

The ROAR friction meter is a good device for testing and analysis by trained technicians but is less well suited for direct use on snowplows. The following observations do not imply any criticism of the ROAR friction meter but are offered as suggested improvements for future friction devices that might be directly mounted on snowplows.

Size

In order to fit a wide range of truck configurations the friction-measuring device must be smaller. Some difficulty was encountered in accommodating the onboard electronics and control boxes. Reducing the size of these components will allow more flexibility in installing the friction units. Reducing the size may also reduce the cost, which is important for widespread use on maintenance fleets. Norsemeter has recognized this factor and is designing a new friction device—SALTAR—that is engineered specifically for mounting on a snowplow. It is smaller, more rugged, and much less expensive than the ROAR unit.

Data Output

The ROAR unit was designed for detailed analysis of road surfaces and produces a wide variety of parameters. However, displaying all of this information is not necessary and can be confusing to drivers/operators. A simple display indicating levels of service (such as that in the PlowMaster display) is more appropriate. In the new SALTAR design, Norsemeter is developing new software that will display a limited number of parameters and will be easier to set up and operate. This is also expected to reduce operator errors and training requirements.

Durability

The environment associated with snowplows is extremely harsh and demanding. Friction devices must be designed to withstand the abuse they will receive and still function reliably. Maintenance requirements must be simple and require little attention. Test tires, which are consumable items, must be inexpensive and easy to replace. Expensive ASTM specification tires may not be required for this operational application. Norsemeter has taken note of this requirement and is incorporating ruggedness as a primary design objective in the new SALTAR design.

Procedures

An important lesson learned was the need for tighter control of data collection and processing. The original plan did not anticipate the difficulties of receiving and processing data in a timely fashion, resulting in a loss of control over the quality of data. Future pooled-fund study phases will incorporate tighter controls to ensure data quality can be monitored closely. Problems caused by operator error will be addressed with new software provided by Norsemeter to make it easier to set up and operate the friction meter.

SUMMARY

The DOTs participating in the project continue to feel that friction is an important condition to measure and monitor via the advanced technology snowplow vehicles. Cooperation with industry is an absolute necessity to identify the needs and requirements of the winter maintenance community. Experiments such as that conducted in Phase II with the Norsemeter friction meter are important as much for what did not work as for what did.

WINTER FRICTION TEST PLAN

1997 - 1998

The testing will be conducted to establish the repeatability and reliability of the Norsemeter friction device. The test will also be used to determine the optimal vehicle speed and frequency of measurements. This test plan is considered necessary to get data from which basic statistics can be obtained. The data will also be used to in the *Test and Evaluation of Friction Measuring Devices for Winter Maintenance Applications* being conducted by the Minnesota Department of Transportation.

The data will be collected during normal winter maintenance activities.

Maintenance Related Testing

- *Use predetermined and fixed routes for all tests
- *Test runs are to be performed when there is:
 - *No danger from the slippery surface
 - *Weather forecasts predict good conditions
- *Sufficient personnel will be available
- *Test routes to include roads when salted and when not salted
- *Test route to include weather stations
- *Measure at normal truck speed in normal traffic
- *Make one data file per route completed

Tests:

1. One test on bare pavement for each section
This is to be done with the ASTM E-274 and the Norsemeter at pavement temperatures below 25 degrees
 2. One test one or two hours before weather conditions require maintenance
 3. One test every time maintenance is performed - one each run
 4. One test 4 - 8 hours after maintenance is completed
- Note: Be sure that no maintenance was performed or that conditions changed
The purpose is to evaluate the maintenance effectiveness

Conditions:

1. Wet and dry snow
2. Hard pack snow
3. Wet ice = when pavement temperature is between 32 degrees and 25 degrees
4. Dry ice = when pavement temperature is below 25 degrees
5. Slush

Figure 8-11 Winter 1997-1998 data collection plan, based on the work plan for Test and Evaluation of Friction Measuring Devices for Winter Maintenance Activities