Historical Overview of Friction Testing in Connecticut

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Report 1

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16. Abstract

A historical overview of pavement friction testing in Connecticut is presented. Photographs of early pavement friction testers are provided, including vintage photos of a skid trailer from a Federal Highway Administration (formally Bureau of Public Roads) demonstration in 1968. Early documents that were pivotal in initiating a pavement friction testing program in Connecticut are cited. It provides insight into a state highway agency's perspective as friction testing services evolved. It covers the equipment used and explains the interpretation of data output. The paper documents Connecticut Department of Transportation (ConnDOT) literature pertaining to pavement friction testing, and lists research studies that have been conducted in Connecticut. ConnDOT polices and procedures are reviewed. Early pioneers in pavement friction testing services are acknowledged.

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ACKNOWLEDGEMENTS

This report is written in memory of the late Mr. George A. Ganung. He was a pioneer for ConnDOT in pavement friction testing services, who was dedicated to his work. He frequently designed and fabricated repairs and improvements to the friction tester at his workshop at home. Tragically, Mr. Ganung was killed in 1987 while responding to an accident in New Hartford, Connecticut for the Volunteer Fire Department as an Emergency Medical Technician (EMT).

Mr. Donald A. Larsen is also acknowledged as a pioneer in pavement friction testing, and for his meticulous record keeping during his many years as Principal Investigator for ConnDOT's Friction Testing and Safety Evaluation Services program. These records, his comments on an early draft, as well as his cited presentation *(5)* greatly facilitated in writing this paper.

Mr. Jeffery J. Scully is acknowledged for his 30-plus years of pavement friction testing services. He recently made his 15th trip to Ohio to participate in the biennial friction tester calibration and correlation services performed at the Transportation Research Center (TRC) in East Liberty, Ohio. Messrs. Frank J. Kos, Eric C. Lohrey, and Eric G. Feldblum are also acknowledged for their contributions to ConnDOT’s pavement friction testing program.

Finally, the author acknowledges the continued cooperation and support of the Federal Highway Administration (FHWA), particularly that of the Connecticut Division (FHWA-CT).

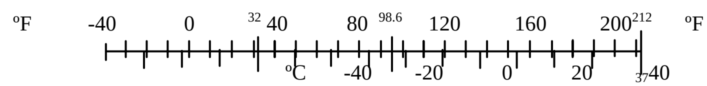
METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
mi^2	square miles	2.59	square kilometers	km^2
ac	Acres	0.405	hectares	ha
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb.)	0.907	Megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		TEMPERATURE (exact)		
ºF	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	ºC

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
km^2	square kilometers	0.386	square miles	mi^2
ha	hectares (10,000 m^2)	2.47	acres	ac
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	Megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		TEMPERATURE (exact)		
ºC	Celsius temperature	9/5 (then add 32)	Farenheit temperature	ºF



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INTRODUCTION

Connecticut Department of Transportation's (ConnDOT's) entry into pavement friction testing began in the early 1950's, when the Traffic Division used a stopping-distance vehicle to perform limited testing on pavements known to be slippery *(1)*. Ganung *(2)* reported that the "stopping-distance" car was a "…standard passenger automobile fitted with a device which fired a chalk pellet onto the pavement at the moment the brakes were applied, thereby enabling the stopping distance to be measured." This method had several faults, and in 1959 consideration was given to building a skid tester based on a General Motors' design, but it was decided that it would be cost prohibitive *(2)*.

Then, in 1967, an NCHRP report was published which suggested that steps be taken and research be conducted to reduce skidding accidents and improve pavement skid resistance *(3)*. ConnDOT officials indicated that this publication "served forcefully" to develop a friction testing program in Connecticut *(1)*. The NCHRP report recommended a tentative minimum skid number of 37 on main rural highways, and higher skid numbers on high-speed roads. The skid number they were referring to was that measured with a ribbed tire in accordance with ASTM E274.

In May 1968, the Federal Highway Administration (FHWA) (formally Bureau of Public Roads) brought a skid trailer to Connecticut and tested several major highways (Figures 1 through 3). The testing demonstrated a need for friction testing in Connecticut, and on October 15, 1968 the Division of Research (formally the Division of Research and Development) submitted an application for a FHWA Safety Grant to purchase a friction tester *(1)*. Strassenmeyer et al. *(1)* indicated that the stated purpose for the grant to purchase equipment and begin a friction testing program was to:

1. Decrease skidding accidents by detecting pavement surfaces with low skid resistance to permit priority scheduling of surface improvements.

2. Evaluate skid resistance of variously surface-textured pavements and their wearing characteristics.

In accordance with the two-year Safety Grant, the intent was to test high frequency accident locations first, and then test the balance of the highway system *(1)*. Therefore, a third reason not listed above to purchase equipment and begin a friction testing program was to perform friction tests at locations identified as having high accident history, especially during wet weather.

FIGURE 1 Photo (rear view) of FHWA friction tester demonstrated to ConnDOT personnel in May 1968.

FIGURE 2 Photo (side view) of FHWA friction tester demonstrated to ConnDOT personnel in May 1968.

FIGURE 3 Photo of FHWA skid trailer demonstrated to ConnDOT personnel in May 1968.

The request was approved and Highway Safety Grant No. HD 69-001-(002) was received with an effective date of April 1, 1969 *(1)*. The Department purchased a one-of-a-kind prototype 1969 TestLab Corporation of Chicago (TestLab) Pavement Friction Tester (Figure 4), and received it in June 1970 *(1)*. After some tweaking, the tester was fully operational by September 1970. As required under the grant, a British Pendulum Tester (Figure 5) was also purchased and was received in May 1970, and a Thruway Skid Cart (Figure 6) was received in November 1969. Ganung *(2)* stated that "both of these devices can be used in places where it would not be possible to use the skid trailer."

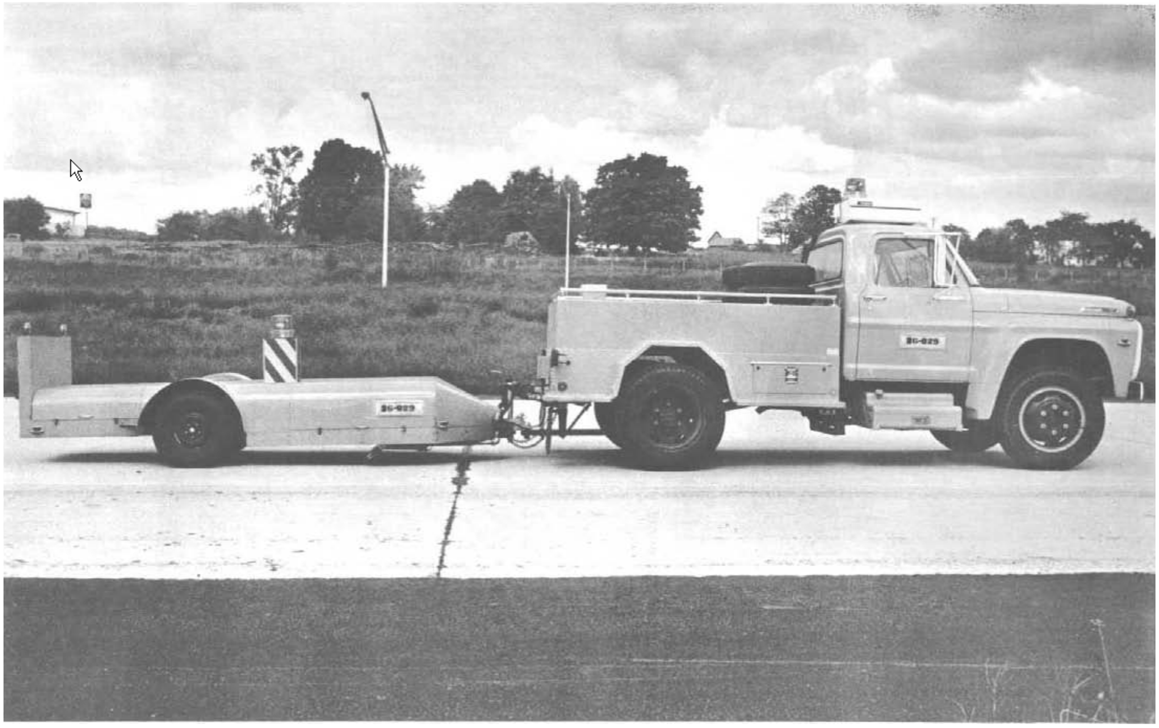

FIGURE 4 1969 TestLab Corporation of Chicago Pavement Friction Tester (a one-of-a-kind).

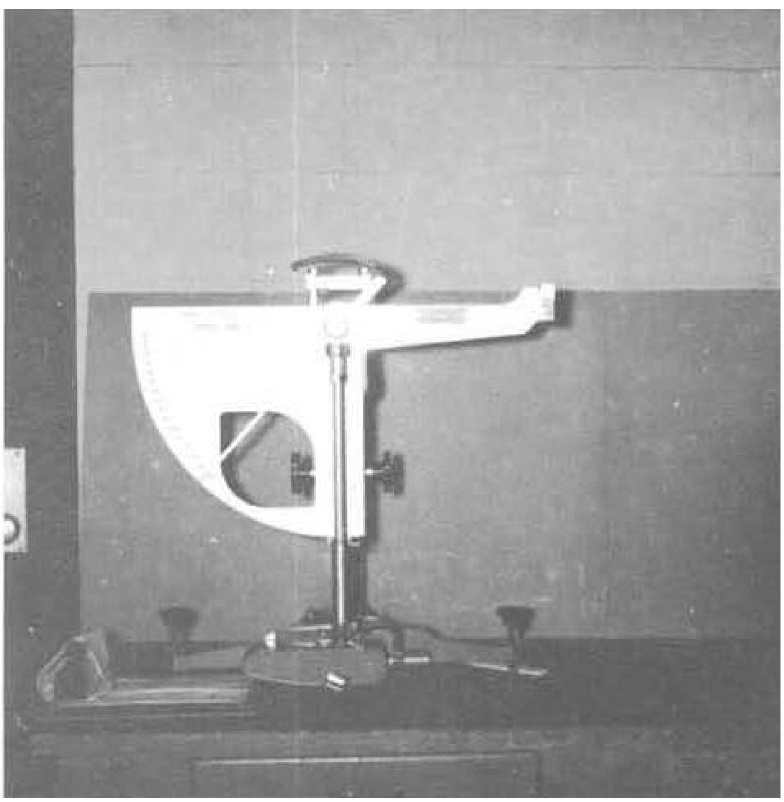

FIGURE 5 British Pendulum Tester required for Highway Safety Grant No. HD 69-001-(002).

FIGURE 6 Thruway Skid Cart required for Highway Safety Grant No. HD 69-001-(002).

THE EQUIPMENT

TestLab Corporation of Chicago Friction Tester (1970-1978)

The TestLab Pavement Friction Tester included a torque-measuring transducer mounted to the trailer’s axle assembly, which provided output directly proportional to the measured torque. It also included a pavement wetting system with a brush attachment, as shown in Figure 7. This provided self-wetted locked wheel testing capabilities. The output was plotted onto a graph during testing with equipment located within the cab of the tester, as shown in Figure 8. A more detailed view of a typical plot, including engineer’s notes, is shown in Figure 9.

FIGURE 7 TestLab Corporation of Chicago Pavement Friction Tester trailer.

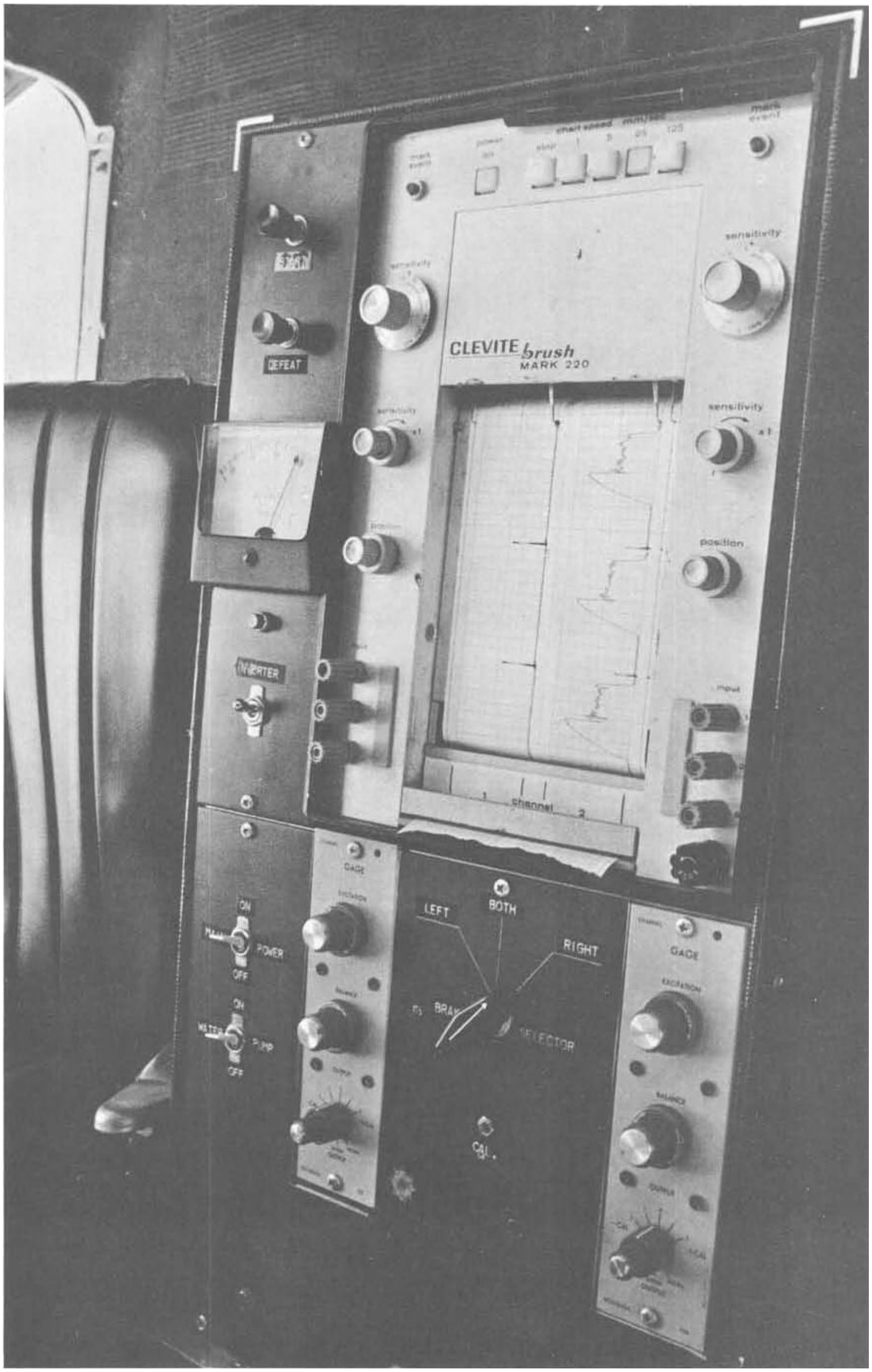

FIGURE 8 Instrumentation inside the cab of the 1969 TestLab Pavement Friction Tester.

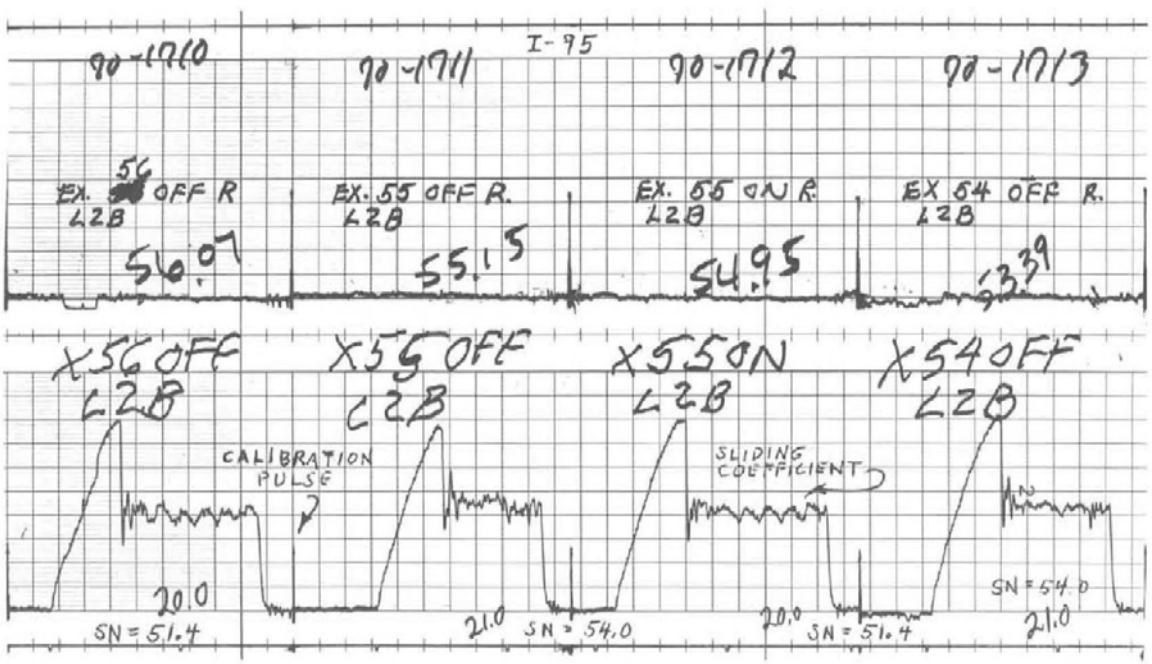

FIGURE 9 Typical plot from 1969 TestLab Pavement Friction Tester including engineer’s notes.

KJ Law Engineers Model 1270 Friction Tester (1978-1989)

The TestLab Pavement Friction Tester was used until 1978, when a KJ Law Engineers Model 1270 Friction Tester was purchased (Figure 10). The Model 1270 included a two-axis force-measuring transducer mounted to the trailer’s axle assembly. Friction numbers were calculated by dividing the traction force by the load. It also included an Ohio State University water nozzle (Figure 11).

FIGURE 10 KJ Law Model 1270 Pavement Friction Tester.

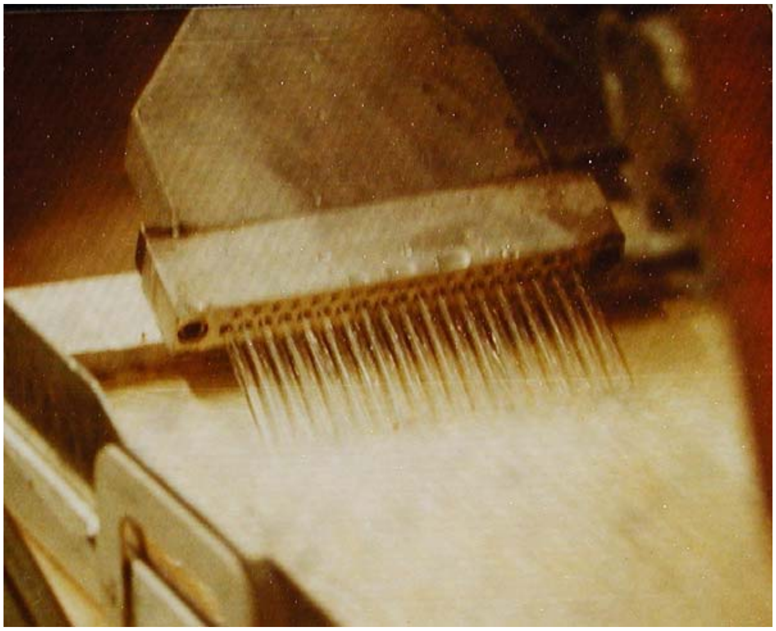

FIGURE 11 Ohio State University water nozzle.

Data were output onto a paper tape (Figure 12) and punch card. Some interpretation of the paper tape was required. Ganung and Larsen provided a description in an in-house Skid Test Operations Manual published in 1982 *(4)*. Tests were presented in pairs of lines. The first six numbers indicated the type of test and the mileage. For example, in the first row of data presented in Figure 12, the number 2 indicates that it was a “regular” test and the next five digits indicate that the test was performed at 4.51 miles. The next seven numbers represent the serial number. In this case it was 8902539. The next three digits represent a friction number of 38.3. The leading 8 on the next line was a code for the computer. The following three numbers were the speed, 36.7. The next five numbers were the route, preceded by a 9 indicating that it was a state route. This was State Route (S.R.) 57. The 0 at the end was a space to accommodate a route with a suffix, such as 71A. The next three digits were the town number, which was 157, Weston. This was followed by a direction (1 equals north), the lane, and the pavement type (2 for asphalt, 1 for concrete). In this case, it was an asphalt pavement. The last digit represented the tire type (0 for ribbed, 1 for smooth). For this test, a ribbed tire was used *(4)*.

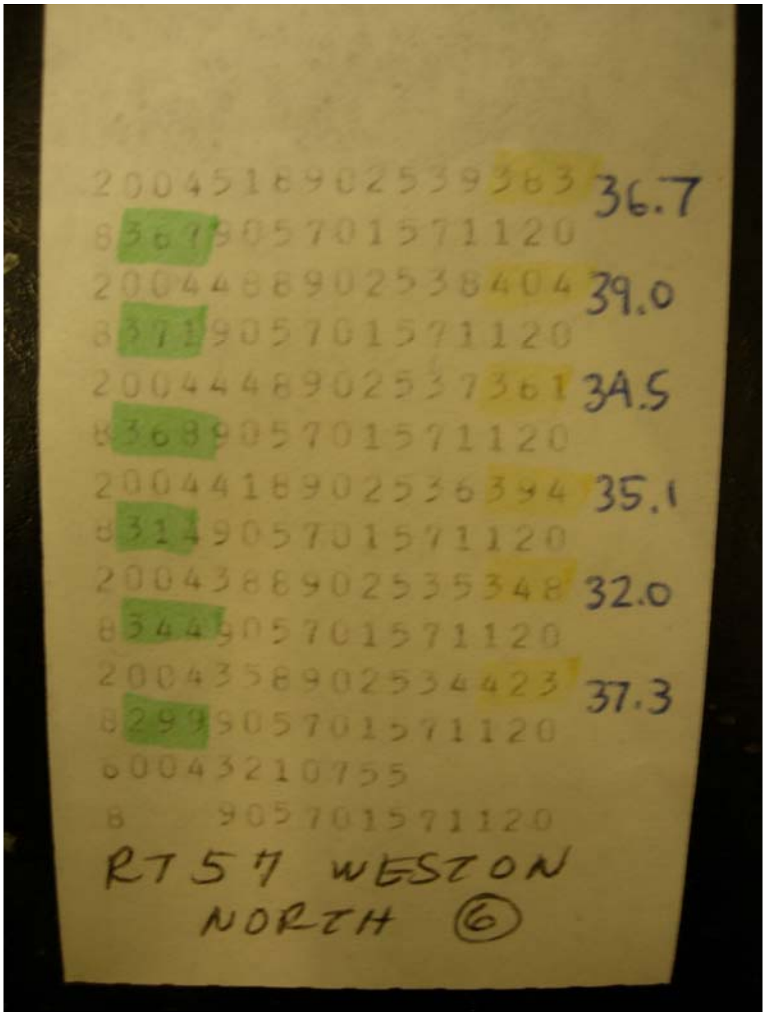

FIGURE 12 Paper tape output with engineers notes.

In looking at Figure 12, note the hand-written numbers in the right margin. These are the ribbed-tire friction numbers corrected to represent the skid resistance measured at a standard test speed of 40 mph. In 1979, ConnDOT officially adopted the policy of converting ribbed-tire friction numbers measured at other test speeds to equivalent numbers measured at the standard test speed of 40 mph. This was documented in an April 10, 1979 memorandum justifying the use of speed correction factors. The equation to calculate the corrected ribbed-tire friction number was and still is as follows:

$FN_{40R} = FN_R - 0.5*(40 \text{ mph} - \text{actual speed})$,

where,

FN_R = Friction Number measured with a Standard Ribbed Tire

and

FN_{40R} = Friction Number with a Standard Ribbed Tire based on a corrected speed of 40 mph.

Note: This correction has been applied to tests performed with a Standard Ribbed Tire only. It has not been applied to tests performed with a Standard Smooth Tire.

KJ Law Engineers Model 1290 Friction Tester (1989-2005)

A KJ Law Engineers Model 1290 Pavement Friction Tester was purchased in 1989 (Figure 13) to replace the Model 1270. Similar to the Model 1270, the Model 1290 included a two-axis force-measuring transducer and Ohio State University water nozzle. The Model 1290 was fully computerized. Data were collected and stored to an on-board computer. Data files were transferred from the on-board computer to 3½-inch floppy disks upon return to the lab, and then copied to personal computers in the office for analysis. ConnDOT engineers developed algorithms to expedite the analysis process.

FIGURE 13 KJ Law Engineers Model 1290 Pavement Friction Tester.

Dynatest Model 1295 Friction Tester (2005-Present)

The Model 1290 was retrofitted in 2000 and was used until 2005, when the current Dynatest Model 1295 Pavement Friction Tester was purchased (Figure 14). The Dynatest Model 1295 (Dynatest) friction tester originally included one two-axis force transducer mounted to the left side of the trailer's axle assembly. It was modified to a dual-sided system in 2007, when another two-axis force transducer was mounted to the right side of the trailer's axle assembly. Thus, the Dynatest is now capable of testing both wheel paths, which allows for several different configurations. The most common configuration used is to have a ribbed tire mounted on the left, and a smooth tire mounted on the right.

FIGURE 14 Dynatest Model 1295 Pavement Friction Tester.

Upgrades from the previous tester include the addition of a High-Speed Selcom Optocator/SLS5000 Laser Sensor (laser profiler) for measuring pavement texture at high speeds (Figure 15), and a Trimble Model AgGPS 33300-00 global positioning system (GPS) for tracking coordinates (longitude and latitude).

For comparison to the aforementioned laser profiler, a Nippo Sangyo Co., Ltd. Circular Track Meter (Figure 16) was purchased in 2006. Pavement macrotexture profiles were measured with the CTMeter in accordance with ASTM Standard E2157. The purpose of comparison was to determine if the high-speed laser profiler macrotexture measurements correlated well with the CTMeter measurements obtained in accordance with the above ASTM test method, and whether or not the high-speed laser profiler could provide viable results.

FIGURE 15 Housing for High-Speed Selcom Optocator/SLS5000 Laser Sensor.

FIGURE 16 Nippo Sangyo Co., Ltd. Circular Track Meter.

CONNDOT PAVEMENT FRICTION TESTING LITERATURE

During the 1970's, ConnDOT performed inventory testing of pavement friction values. These included a primary system inventory from 1970 to 1972, a secondary system inventory from 1972 to 1973, and an interstate and primary system inventory from 1974 to 1975 and again from 1978 to 1980 *(5)*. Results of these friction surveys were published in several ConnDOT reports *(6,7,8,9,10)*. ConnDOT was also involved in pavement friction testing research studies. These included "Development and Implementation of a Skid Test Program in Connecticut" from 1969 to 1972, "Friction Characteristics of Paving Materials in Connecticut" from 1971 to 1974, and "Wet Weather, High-Hazard Accident Locations: Identification and Evaluation" from 1974 to 1979 *(5)*. The research work included several publications *(11,12,13,14,15)*, some of which have been frequently referenced by others.

In April 1975, ConnDOT published a report titled "State and Local Friction Testing Services for Connecticut." Ganung *(16)* indicated that continuously available friction testing services were essential for both State and local municipalities. He cited a U.S. Department of Transportation Highway Safety Program Manual, Transmittal 18, dated February 1974: "Each State and local government should have a program for resurfacing or other surface treatments to correct street and highway locations where inadequate skid resistance contributes to high-accident experience." The objective of the program was to provide friction-testing services to the State, towns and municipalities to reduce wet-weather accidents *(16)*.

The results of the inventory testing demonstrated that the aggregates and mix designs used in Connecticut were sufficient to provide adequate levels of skid resistance for the majority of state roadways *(17)*. Ganung (*8)* indicated that many of the low friction numbers measured during the survey were "…scattered, in noncritical areas, or in congested locations where average speeds are quite low." Larsen and Feldblum noted that the lower values "were usually associated with high volume sharp curves, ramps or intersections, and in some cases, worn PCC pavements." ConnDOT engineers, in concurrence with the FHWA CT-Division Office, decided to discontinue inventory level friction testing in 1980. They decided that a by-request-only program would be more practical, which led to the testing of many curves and intersections *(17)*.

Larsen and Feldblum identified four scenarios for which friction test requests have generally been made in Connecticut since 1980 *(17)*: "…1. justification for overlays or surface treatments to correct areas of deficient surface friction; 2. accident investigations, where attorneys request data corresponding to roadways on which specific accidents occurred; 3. identified by the Traffic Engineering unit using the Department's Suggested List of Surveillance Study Sites (SLOSSS); and 4. evaluation and monitoring of experimental pavements or surface treatments." Note: the SLOSSS is basically a list of statistically identified areas with higher than expected accident rates. Wet-weather high-hazard areas have been of particular interest to Traffic Engineering, and many of their requests have been generated from the ConnDOT Wet Pavement SLOSSS.

CONNDOT POLICIES AND PROCEDURES

A Commissioner's Administrative Memorandum (No. 15) was issued on April 11, 1974 in order to establish ConnDOT policy for pavement friction testing *(16)*. The ConnDOT policy contained in the memorandum was stated: "All roadway and airport surfaces, owned and maintained by this Department, shall be maintained so as to provide an acceptable level of surface friction for the traffic passing over the pavement surface." The memorandum also included a friction testing request procedure. It stated that pavements suspected of having low friction were to be referred to the Division of Research for field friction tests. The Division of Research was required to forward any available existing friction testing results to the requesting party within five working days. Next, the Division of Research was required to schedule, complete and forward results of new friction tests to the requesting unit within 10 working days. Copies of all correspondence were required to be forwarded to the Office of Maintenance and the Division of Traffic for corrective action *(16)*.

Since ConnDOT no longer performs inventory level friction testing, existing recent friction testing results for a given location rarely exist. Many years have passed since the abovementioned Commissioner’s Administrative Memorandum was issued, and new generations of employees responsible for friction testing were not familiar with its existence until this literature search was performed. However, the Division of Research has been prompt about performing friction tests upon request, and the Office of Maintenance and Division of Traffic are still sent copies of all friction testing correspondence.

Starting July 1, 1990, ConnDOT has provided friction testing and roadway safety evaluation services as part of a State Planning and Research (SP&R) project (HPR-1417). These services are provided by the ConnDOT Division of Research to other ConnDOT offices and Connecticut Municipalities upon request, in order to ensure that all roadway surfaces owned or maintained by this Department provide an acceptable level of surface friction *(18)*.

Since the mid-1970's, ConnDOT pavement friction testers have been biennially correlated and calibrated at the Evaluation and Field Test Center located within the facilities of the Transportation Research Center Inc. in East Liberty, Ohio. These services are performed in order to reduce interstate variation in skid measurements of pavement surfaces. They also ensure that ConnDOT's friction tester meets ASTM E274 Standards, and that any data obtained with the friction tester that might be used in court cases will be acceptable.

CURRENT RESEARCH

A research study titled "Enhancements to ConnDOT's Pavement Friction Testing Program" was started September 1, 2004. The objectives of this study as stated in the proposal *(17)* are to (1) update friction number speed correction factors based upon pavement mix designs currently in use in Connecticut with an upgraded friction tester (hardware and software), (2) research relationships between texture and friction, (3) evaluate the potential use of the International Friction Index (IFI) in

Connecticut in accordance with ASTM E 1960, and (4) implement the appropriate latest technology and procedures for pavement friction data request, collection and processing. Note: ASTM E 1960 *(19)* states “the IFI consists of two parameters that report the calibrated wet friction at 60 km/h (F60) and the speed constant of wet pavement friction (S_p).” The IFI “allows for the harmonizing of friction measurements with different equipment to a common calibrated index.”

A Connecticut Cooperative Transportation Research Program (CCTRP) study is also being conducted by the University of Connecticut (UConn). The title of this research is “Incorporating Wet Pavement Friction into Traffic Safety Analysis.” Professor John N. Ivan is leading a research team to conduct a statistical analysis to study the relationship between wet pavement friction and road safety experience. A final report for this project is anticipated in 2010.

ConnDOT is also participating in Transportation Pooled Fund Study TPF-5(141), “Pavement Surface Consortium: A Research Program.” The Virginia Department of Transportation is the lead agency and the contractor is Virginia Tech. This pooled-fund study complements ConnDOT’s own research because its objective is to enhance “the level of service provided by the roadway transportation system through optimized pavement surface texture characteristics." Study partners include the FHWA, Connecticut, Georgia, Mississippi, Pennsylvania, and South Carolina. The pooling of technical expertise from these other state agencies and Virginia Tech has been extremely beneficial to Connecticut's own friction testing program thus far.

Through FHWA, the Virginia Transportation Institute, and the above pooled-fund study, ConnDOT recently took loan of a pavement surface friction device called the GripTester®. This differs from the locked-wheel friction tester currently owned by the department in that it includes a fixed-slip design, which measures drag and load continuously. Considering the advent of anti-lock brakes and the fact that it measures friction in the wheel path continuously, the fixed-slip design may be more appropriate for highway applications than the locked-wheel design. Between September 14 and October 1, 2009, ConnDOT researchers took friction measurements on several different roadways in Connecticut. These data will be analyzed and compared to measurements taken with the Dynatest Model 1295 tester.

FIGUIRE 17 GripTester® Skid Resistance (Surface Friction) Tester.

TRANSPORTATION RESEARCH BOARD'S 89th ANNUAL MEETING

On January 12, 2010, ConnDOT staff presented Transportation Research Board (TRB) Paper 10-0426 *(20)* titled, "Historical Overview of Pavement Friction Testing in Connecticut" in a Meet the Author Poster Session at the TRB 89th Annual Meeting in Washington, D.C. The poster session was sponsored by the *Surface Properties – Vehicle Interaction Committee* (AFD90). This was Session 580 titled "Traveled Surface Texture, Friction, Noise, and Profile." A photo of the display presented there is shown below in Figure 18.

FIGURE 18 ConnDOT Research staff (left to right) Robert Kasica, John Henault, Anne Marie McDonnell, and Dionysia Oliveira at poster session.

CONCLUSIONS

Just as Strassenmeyer et al. *(1)* wrote a report following the 1968 skid trailer demonstration, ConnDOT researchers will prepare a report to document the GripTester® loan. Over 40 years have passed since the FHWA skid trailer demonstration, but the report still serves as a valuable reference. This and other references cited in this paper were also valuable in preparing this overview, which will provide future employees with a concise historical reference. This fits into the succession planning that should take place within a state highway agency prior to retirements and changes in employee responsibilities.

To put Connecticut's efforts into perspective, results of a National Cooperative Highway Research Program (NCHRP) synthesis study *(21)* questionnaire showed that "the majority of the responding states use the ASTM locked wheel test method with the standard ribbed tire." Side force and fixed slip methods (such as the GripTester®) with smooth tread tires are more common outside the United States. The synthesis report suggested that macrotexture measurements be taken in addition to friction measurements. ConnDOT engineers have the equipment to measure macrotexture either at highway speeds (High-Speed Selcom Optocator/SLS5000 Sensor) or with the more precise static CTMeter instrument.

The FHWA issued a technical advisory entitled *Surface Texture for Asphalt and Concrete Pavements (22)*, which suggests pavement texture targets be established by owner-agencies based upon project specific factors, such as roadway geometry. ConnDOT researchers have been measuring texture depths to begin characterizing different pavement designs. Future research should focus on setting texture targets and integrating texture depth and friction measurements, including calculation of IFI parameters.

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22. *Surface Texture for Asphalt and Concrete Pavements*. FHWA Technical Advisory, Classification Code T 5040.36,

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APPENDIX A

TRB 89th Annual Meeting

Meet the Author Poster Session 580
Traveled Surface Texture, Friction, Noise, and Profile

Tuesday, January 12, 2010
7:30-9:30 PM, Shoreham, Blue Room Foyer

Sponsored by Surface Properties – Vehicle Interaction Committee

Historical Overview of Pavement Friction Testing in Connecticut
TRB Paper 10-0426

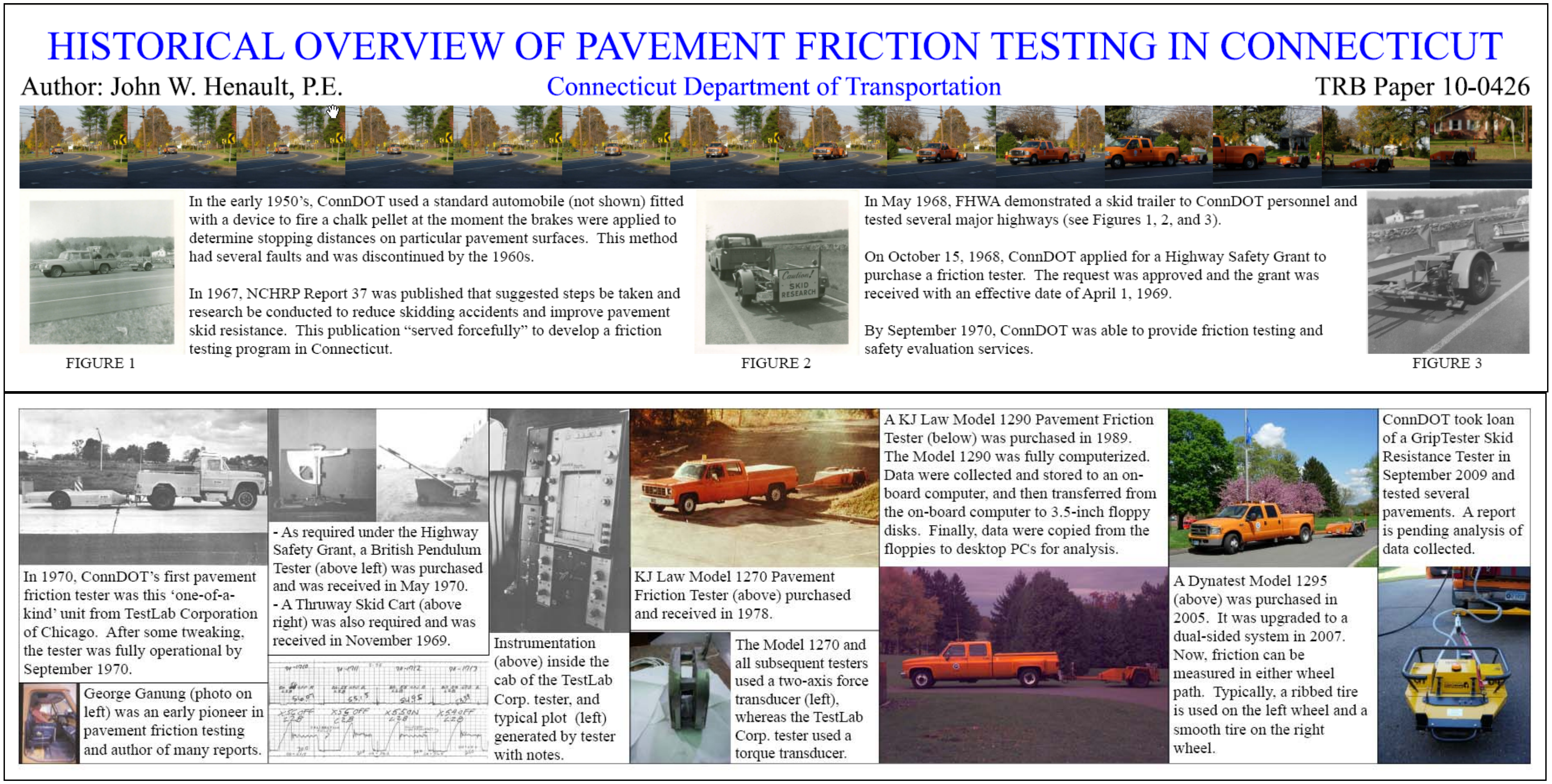


Figure A-1 Poster presented at Meet the Author Poster Session 580 titled "Traveled Surface Texture, Friction, Noise, and Profile" on January 12, 2010 at the TRB 89th Annual Meeting in Washington D.C.

Welcome

TRB Committee on Surface Properties - Vehicle Interaction (AFD90)

Scope

This committee is concerned with the interactions between vehicle and pavement surfaces as they affect safety, comfort, convenience, and economics, including user costs. It promotes the evaluation, modeling, and understanding of these interactions and the studies that identify, quantify, measure, and model the factors that influence these interactions. It assists in the establishment of limiting criteria for the factors and encourages the application of results toward the improvement of the vehicle-surface property relationship.

Kevin K. McGhee, Chair
George K. Chang, Secretary
Stephen F. Maher, TRB Staff Member

Amy Simpson, Communications Coordinator
alsimpson@mactec.com

FIGURE A-2 TRB Committee on Surface Properties – Vehicle Interaction (AFD90) welcome.

PAVEMENT FRICTION TESTING IN CT

HISTORICAL OVERVIEW **TRB PAPER 10-0426**

In 1970, ConnDOT's first pavement friction tester was this 'one-of-a-kind' unit from TestLab Corporation of Chicago

Historical Overview of Pavement Friction Testing in Connecticut - TRB Paper No. 10-0426

Early Milestones:

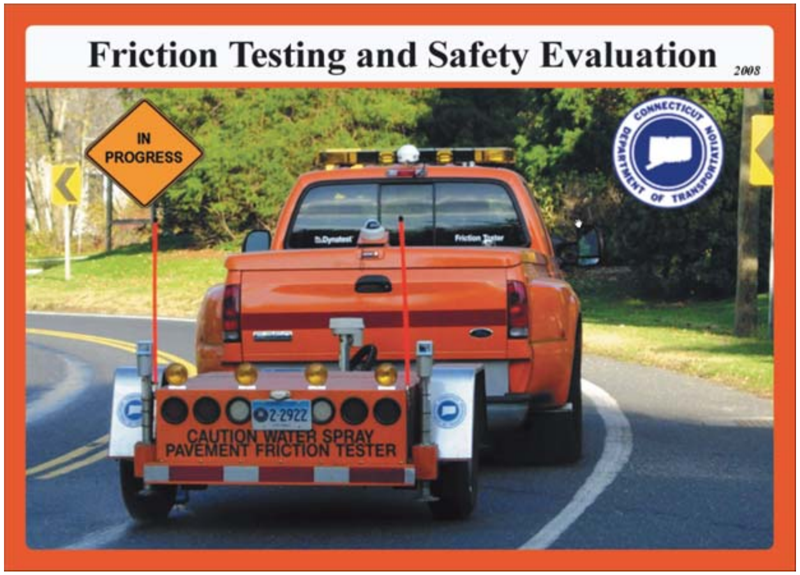
- **1950's:** ConnDOT used a standard automobile fitted with a device to fire a chalk pellet at the moment the brakes were applied to determine stopping distances on pavement surfaces. This method had several faults and was discontinued by the 1960's.
- **1967:** NCHRP Report 37 was published that suggested steps be taken and research conducted to reduce skidding accidents and improve pavement skid resistance. This publication "served forcefully" to develop a friction testing program in Connecticut.
- **May 1968:** The Bureau of Public Roads (FHWA) demonstrated their friction tester to ConnDOT personnel by testing several major highways in Connecticut.
- **October 1968:** ConnDOT applied for a Highway Safety Grant to purchase a friction tester. The request was approved and the grant was received with an effective date of April 1, 1969.
- **June 1970:** ConnDOT received a one-of-a-kind 1969 TestLab Corporation of Chicago Pavement Friction Tester. After some tweaking, the tester was fully operational by September 1970.

89th TRB Annual Meeting in Washington, D.C., Meet the Author Poster Session

- **Author:** John W. Henault, P.E., john.henault@ct.gov, 860-258-0352
- **Event:** Session Number 580, "Traveled Surface Texture, Friction, Noise, and Profile"
- **Event Date and Time:** Tuesday, January 12, 2010, 7:30 PM to 9:30 PM
- **Event Location:** Shoreham, Blue Room Foyer
- **Sponsored By:** Committee on Surface Properties - Vehicle Interaction (TRB AFD90)

ConnDOT online research reports: http://www.ct.gov/dot/researchreports
SPR-2243: A Connecticut DOT project conducted in cooperation with U.S. DOT FHWA

FIGURE A-3 Trading card developed for and distributed at the TRB 89th Annual Meeting in Washington, D.C.



FRICTION TESTING AND SAFETY EVALUATION SERVICES

FREE REPORTS AVAILABLE @ WWW.CT.GOV/DOT/RESEARCHREPORTS

Project Title: "Friction Testing and Safety Evaluation Services"

Objectives: Provide friction testing and roadway safety evaluation services to Connecticut Department of Transportation (ConnDOT) offices upon request to ensure all roadway surfaces provide an acceptable level of surface friction for prevailing traffic conditions.

Methodology: The ConnDOT's wet pavement "Suggested List of Surveillance Study Sites" (SLOSSS) high accident locations or areas suspected of having slippery pavement are identified and tested for wet-weathered skid resistance. The results are summarized, analyzed, and reported to the requester.

Equipment: 2005 ASTM E274 Dual-Sided Pavement Friction Tester (DynaTest) with a texture measurement laser device and GPS system.

Program Implementation: 1969

Principal Investigator:
John W. Henault, P.E. Phone: 860-258-0352 Email: john.henault@po.state.ct.us

SPR-1417: Project conducted in cooperation with the U.S. DOT Federal Highway Administration

ENHANCEMENTS TO THE PAVEMENT FRICTION TESTING PROGRAM IN CONNECTICUT

RESEARCH-IN-PROGRESS (RIP)
ON THE WEB @ WWW.CT.GOV/DOT/RESEARCH

Objectives: The Connecticut Department of Transportation (DOT) is researching the relationship between pavement friction and texture; the effects of roadway geometry on friction measurements; potential use of the International Friction Index; and, development of speed correction factors for friction numbers measured at speeds below/above 40 mph.

Project Description:

1. Implement a new pavement friction tester with texture measurement capabilities;
2. Develop speed correction equations for pavement friction measurements;
3. Evaluate the effect of roadway geometry on friction measurements;
4. Compare texture measurements with those from a Circular Track Meter; and,
5. Utilize texture measurements to evaluate use of the International Friction Index (IFI).

Final Report Anticipated: June 2008

Principal Investigator:
John W. Henault, P.E. Phone: (860) 258-0352 Email: john.henault@po.state.ct.us

SPR-2243: A project prepared in cooperation with the U.S. DOT Federal Highway Administration (FHWA)

FIGURE A-4 Additional Friction Testing trading cards distributed at the TRB 89th Annual Meeting.

APPENDIX B

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 37

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 37

TENTATIVE SKID-RESISTANCE REQUIREMENTS FOR MAIN RURAL HIGHWAYS

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 37

TENTATIVE SKID-RESISTANCE REQUIREMENTS FOR MAIN RURAL HIGHWAYS

H. W. KUMMER AND W. E. MEYER
DEPARTMENT OF MECHANICAL ENGINEERING
THE PENNSYLVANIA STATE UNIVERSITY

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS IN COOPERATION WITH THE BUREAU OF PUBLIC ROADS

SUBJECT CLASSIFICATION:
PAVEMENT PERFORMANCE
HIGHWAY SAFETY

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING 1967

TENTATIVE SKID-RESISTANCE REQUIREMENTS FOR MAIN RURAL HIGHWAYS

SUMMARY

A skid number of 37 is recommended as the tentative minimum requirement for pavement friction on main rural highways. This skid number (defined as the friction coefficient of a tire sliding on a wet pavement times 100) is that measured with a skid trailer in accordance with ASTM Method E-274 at 40 mph in the most polished track of the road (usually the left wheel track of the traffic lane) during summer or fall.

For high-speed roads higher skid numbers, as measured at 40 mph, are explicitly recommended to compensate for the reduction of the friction between the tire and the wet pavement with speed. The recommendations are also expressed in terms of values obtained by the stopping distance method and with portable testers.

The recommended minimum requirements are based on the normal frictional needs of traffic as derived from driver behavior studies. The values so obtained are in close agreement with those from accident studies which promise a substantial reduction in accident frequency. A program of further research to improve the basis from which more definitive minimum requirements or standards can be derived is suggested.

The principal problems and causes of pavement slipperiness, the mechanism of rubber and tire friction and the various methods of measuring friction are reviewed with the object of elucidating the problems connected with specifying minimum skid-resistance requirements. Steps which can be taken and research which is needed to reduce skidding accidents and to improve the skid resistance of pavements are suggested.

CHAPTER ONE

INTRODUCTION

In this chapter, recent developments which have led to the need for this study and its objectives and scope are presented. The physical significance of the term "pavement slipperiness" and the principal problems and causes of pavement slipperiness are discussed.

BACKGROUND OF THE STUDY

Slippery pavements have been known to exist for more than four decades, but the causes of slipperiness, its measurement, and its effect on the safety of vehicular traffic were not regarded as matters of great concern prior to 1950.

Although reliable skidding accident data are difficult to come by, those in existence suggest that the skidding accident *rate* is on the increase and has now reached proportions which can no longer be ignored. This trend may be partly due to improved accident reporting, collection, and evaluation methods, but it is undoubtedly also a reflection of a gradual increase in vehicle speeds and a significant and progressive increase in traffic density.

More rapid acceleration, higher travel speeds, and faster deceleration, made possible by modern highway and vehicle design and fully utilized by a greater number of younger