DETERMINATION AND IMPROVEMENT OF RELEVANT PAVEMENT SKID COEFFICIENTS

MICHIGAN
HIGHWAY RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

DETERMINATION AND IMPROVEMENT OF RELEVANT PAVEMENT SKID COEFFICIENTS

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Progress Report on a Highway Planning and Research Project
Conducted in Cooperation With
The Federal Highway Administration

Research Laboratory Section
Testing and Research Division
Research Project 69 G-173
Research Report No. R-783

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INTRODUCTION

Background

In February 1970, a research proposal for this study was submitted to the Federal Highway Administration for approval under the Highway Planning and Research Program. In a letter dated June 15, 1970 to Henrik E. Stafseth, State Highway Director, the proposal was "... approved for the purpose of initiating the study." by G. D. Gibson, Jr., Acting Division Engineer, Bureau of Public Roads. Mr. Gibson stated that before the second year's work would be approved, an expanded work plan for the remainder of the study should be submitted. Further, in meetings with representatives of the FHWA on October 29, 1970 and May 12, 1971, it was agreed that temporary approval would be granted for extending the study past July 1, 1971, pending approval of the remainder of the project. Also, John Watson, FHWA, Washington, D. C. asked that more information be provided describing Michigan's experience in pavement skid research. This report includes a discussion of Michigan's history in pavement skid research, a discussion of accomplishments during the first year of the HPR study, and a description of planned work for the remainder of the study.

History of Michigan Experience

In 1947, the Research Laboratory began an active skid research program when it investigated a 140 mile length of US 2 between St. Ignace and Escanaba. Measurements were made using the stopping distance method; that is by locking the brakes on a moving automobile and measuring the stopping distance. As a result of the 1947 study, manufactured limestone sand was prohibited from use in pavement surfaces and the pavement under investigation was resurfaced.

In 1954, concurrently with the General Motors Corporation, development of a skid trailer began. The basic trailer, constructed from a salvaged 1949 Buick chassis, is still used extensively. Appendix A describes the equipment now used by the Department for operational skid testing. The program has mushroomed to its current status where the Laboratory makes an average of almost 8,000 skid tests each year. Appendix B is a sample annual report of skid tests; such reports have been published each year since 1965. Prior to that time, reports of individual or groups of tested projects were published throughout each year, as necessary.

Currently, pavements falling in each category listed below are tested annually. The list is arranged in order of priority.

1) high-accident areas
2) special requests
3) experimental surfaces
4) new surfaces
5) surfaces after five years service.

Naturally, after so many years of pavement friction testing, questions were generated which should have been researched. However, because of the large number of tests required to complete the preceding list of operational demands, the Department's skid measuring instrument was never free for use in research.

Finally, it was decided that a new friction measuring instrument must be procured and, at least initially, used primarily for research. Planned research was described in the proposal for Michigan Project 69 G-173, as submitted to the FHWA.

ACCOMPLISHMENTS DURING PAST YEAR

Pavement Texturing

Although a study of textured pavement was planned for this project, it was decided to proceed with experimental texture finishing of a new concrete surface in July 1970. Since the proposal for Michigan Project 69 G-173 had not been approved in early summer, when texturing was to be done, the work was outlined under Experimental Highway Construction Work Plan No. 8 and Research Project 70 F-114, "Broomed Concrete Pavement Surface."

Under Research Project 70 F-114, experimental concrete finish textures were applied longitudinally and transversely with nylon brushes and transversely with metal combs. After comparing the initial skid resistance of the experimental surfaces with that obtained by Michigan's conventional burlap drag, it was decided to modify Department specifications to require transverse brush finishing on contracts let in and after 1972. For contracts let in 1971, brush texture finishing is optional.

The initial report for Research Project 70 F-114 is included in Appendix C. Textured surfaces will be tested periodically to determine wear resistance, additional comb texturing will be tried, and the specified finish may possibly be modified again.

Acquisition of Pavement Friction Measuring Instrument

In order to carry out planned research, it was necessary to acquire a pavement friction measuring instrument in addition to the one developed and currently being used by the Research Laboratory. The existing instrument was in almost constant use performing operationally required tests and it did not have the versatility necessary for planned research. The new instrument, a General Motors Proving Ground Model 2 Coefficient of Friction Vehicle, was purchased from K. J. Law Engineers, Inc., Detroit, Michigan. Specifications for the instrument, marketed by K. J. Law Engineers as a Model 965 Surface Dynamics Pavement Friction Tester, are provided in Appendix D.

The instrument was delivered on April 28, 1971 immediately after representatives of the Laboratory had completed a three day school conducted by K. J. Law Engineers. Since the equipment has been received, the majority of time has been spent making minor repairs and adjustments on it.

Survey of Tire Characteristics

Since pavement friction values are a function of both the pavement surface and the characteristics of the tire sliding over the surface, an investigation was made of tires used on vehicles in Michigan. A survey was made of Michigan vehicles to determine what proportion of vehicles had tires falling into the following categories:

1) Smooth tires
2) Snow tires
3) Studded tires.

Since each of the three items in the preceding list is known to affect vehicle tracking and braking, a knowledge of the proportion of vehicles with each type tire permits better application of pavement friction test results. In a survey conducted between January 11 and February 19, 1971, tires were found to exist proportionally in the following broad categories:

a) About 15 percent of all cars had at least one smooth tire
b) About 44 percent of all cars had snow tires
c) About 15 percent of all cars had studded tires.

A further breakdown of these data and details of the survey are given in Appendix E, "A Survey of Vehicles Using Studded, Smooth, or Snow Tires in Michigan." Bills to prohibit studded tires in Michigan have been introduced in the Legislature. However, until they are passed, annual surveys will be made to determine proportions of vehicles with studded tires as well as those with snow and smooth tires. Tire studs are an important factor not only with respect to effects on the vehicle using them but also because of the pavement damage they cause.

Relating Pavement Materials and Traffic to Pavement Friction

Plans were to select pavements where friction had been measured for the past several years and relate the change in friction to construction materials and traffic. However, pavement surfaces have been damaged so rapidly since the introduction of tire studs, that this study must be revised.

PROPOSED WORK

Repair and Familiarization

First, operating problems with the newly acquired pavement friction measuring unit must be solved. Steps have been taken to provide additional cooling of electronic components and defective parts are now being replaced or repaired. After the unit is repaired, familiarization will be continued.

Comparison of New and Old Units

When the operators have attained proficiency with the equipment, an attempt will be made to relate its measurements to those made by the older unit. Sites will be selected as follows:

1) Four sites with wsf coefficients less than 0.35
2) Four sites with wsf coefficients greater than 0.65
3) Two sites with wsf coefficients between 0.35 and 0.45
4) Two sites with wsf coefficients between 0.45 and 0.55
5) Two sites with wsf coefficients between 0.55 and 0.65.

Within each class of coefficients, pavement surfaces will be equally divided between rigid and flexible. For site selection, coefficients will be based on measurements made by the older unit traveling at 40 mph on a wet surface.

Testing procedure for each site is shown in Figure 1. All tests at any selected site will be completed in the same day. Individual tests will follow sequentially as soon as the pavement surface has dryed from the preceding test. A total of 336 tests will be made with 24 tests at each site.

Analysis of variance will be used to determine:

1) If a significant difference exists between measurements made by the two instruments. If there is a difference, correlation between the two units will be attempted with paired test values being the random variables.

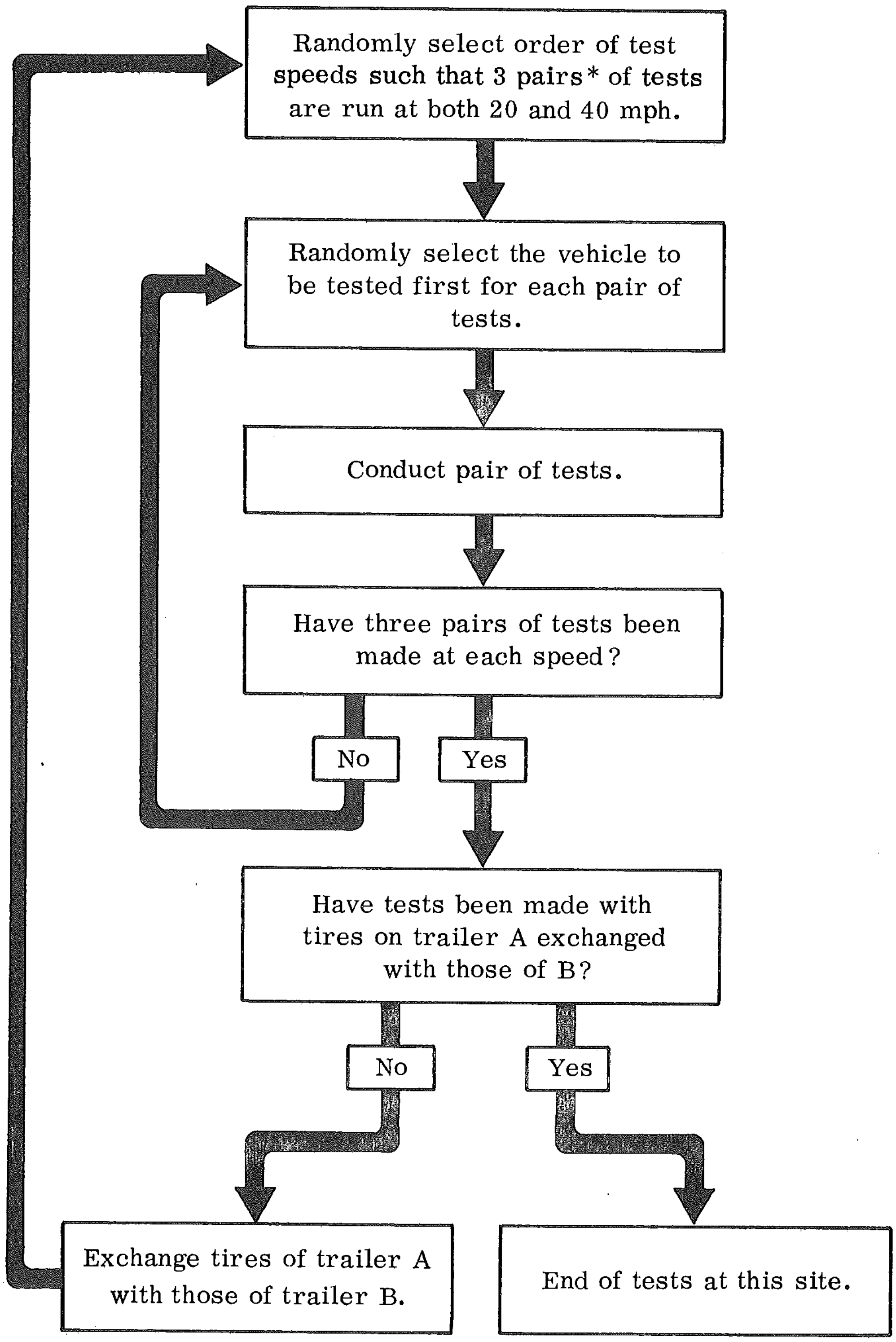
2) If a significant difference exists between measurements made by the two sets of tires. If there is a difference, a further investigation of this effect must be made.

3) If there is any interaction between test unit and pavement type.

Seasonal and Temperature Effects

Giles and Sabey (1) showed how wet skidding accidents varied directly with mean monthly air temperature. Their work strongly suggested that increasing temperatures resulted in lower friction levels. Other studies (2, 3,) have shown wet surface temperature to directly affect friction values. There is disagreement regarding the slope of the friction vs. temperature curve; therefore, that relationship will be investigated in Michigan. In addition to temperature, it has been suggested that other climatological factors such as precipitation have affected pavement friction (3). These factors will also be examined.

A length of concrete pavement that is closed to traffic is available for use as a friction measuring site. A portion of this pavement will be resurfaced with a bituminous mat so temperature and seasonal effects on both rigid and flexible surfaces can be investigated. Both impending and locked-wheel tests will be made at about two-week intervals except when prohibited by freezing weather. The two-week interval between measurements may be supplemented with additional measurements made when temperatures are very high or before and after heavy precipitation. As a means of investigating effects other than temperature and precipitation, friction measurements will also be made on nearby pavements which are open to traffic. Such pavements will be selected so that each has a significantly different traffic density. This should provide information on effects of such factors as traffic and de-icing chemicals. Times between



*NOTE: Tests will be made in pairs. Each pair will consist of one test by each unit at the same speed and as close together in time as feasible.

Figure 1. Comparison of two pavement friction measuring units, A and B at a test site.

tests on both the control pavement and those open to traffic will be as small as possible. A rain gage will be installed at the control test site so precipitation can be considered.

Aggregates and Traffic

Pavement friction and traffic volume data are available for the past several years. However, great caution must be exercised in using historical data since surface damage caused by studded tires has altered past traffic wear patterns. Tire studs were permitted in Michigan as a result of a law passed in June 1967. However, bills have been introduced into the State Legislature which would ban studded tires in Michigan. Although it is likely that studded tires will be banned in the near future, the anomalous effects on pavement friction have already been introduced. To minimize the effects of tire stud damage, in our study, two approaches will be tried. First, only historical data taken through 1967, when studs were first introduced, will be investigated. There may be data for projects where traffic-aggregate relationships have developed to a point where conclusions may be drawn. Second, pavements with data taken through the present time will be investigated, but only when there is little or no visible tire stud damage.

In total, about 40 pavements will be selected. An attempt will then be made to relate rate of change of friction with traffic and aggregate. Among the aggregate characteristics to be investigated are texture, shape, size, permeable voids, and mineral composition. Because many of the pits used in producing aggregates for the pavements under investigation are no longer operating, many characteristics of the aggregates will be evaluated by visual inspection and color photographs of each pavement.

Comparison of Impending and Locked-Wheel Skidding

Since the older Michigan pavement friction measuring device has not been used for measuring impending skid values, no experience has been attained on that subject. However, non-skid brakes are now available on cars and may become very popular. Therefore, it is planned to simply measure impending as well as locked-wheel friction values on most tests made for other phases of this study. As part of the statistical analysis, impending skid friction will be compared to locked-wheel and the possibility of relating it to speed, texture, etc. will be investigated.

Effects of Speed

In the past, friction measurements on Michigan pavements were made at speeds of 20 and 40 mph. These speeds are unrealistic for measuring friction on freeways where traffic may legally move at 70 mph. It is important, then, that investigations of roadway friction values include the higher more realistic speeds.

Several past studies have shown the slope of the speed vs. friction curve to be a function of pavement texture. We plan to evaluate existing methods of texture measurement, select the most desirable one, and try to relate slopes of speed vs. friction curves to texture values. Individual projects will then be inspected closely to try and determine whether texture may be intrinsically incorporated into a pavement through mix design or materials selection.

SUMMARY

Michigan began measuring pavement friction about 24 years ago and has measured and accumulated historical friction data on pavements throughout the State. However, because of operational priorities, the Michigan friction test trailer has not been free for research use. Therefore, a new test instrument has been procured for research and will be compared with the older unit.

Also, during the past year, special textured finishes have been applied to a pavement and initial evaluations made. A survey of the extent of use of snow, studded and smooth tires has been completed.

Proposed work has been discussed in this report and a schedule is shown in Figure 2.

REFERENCES

1. Giles, C. G. and Sabey, B. E. "A Note on the Problem of Seasonal Variation in Skidding Resistance," Proceedings 1st International Skid Prevention Conference, Virginia Highway Res. Council, Part 2, pp. 563-568, 1959.

2. Finney, E. A. and Brown, M. G., "Relative Skid Resistance of Pavement Surfaces Based on Michigan's Experience," Ibid., pp. 435-457, 1959.

3. Kummer, H. W. and Meyer, W. E. "Tentative Skid-Resistance Requirements for Main Rural Highways," NCHRP Report 37, Highway Research Board, 1967.

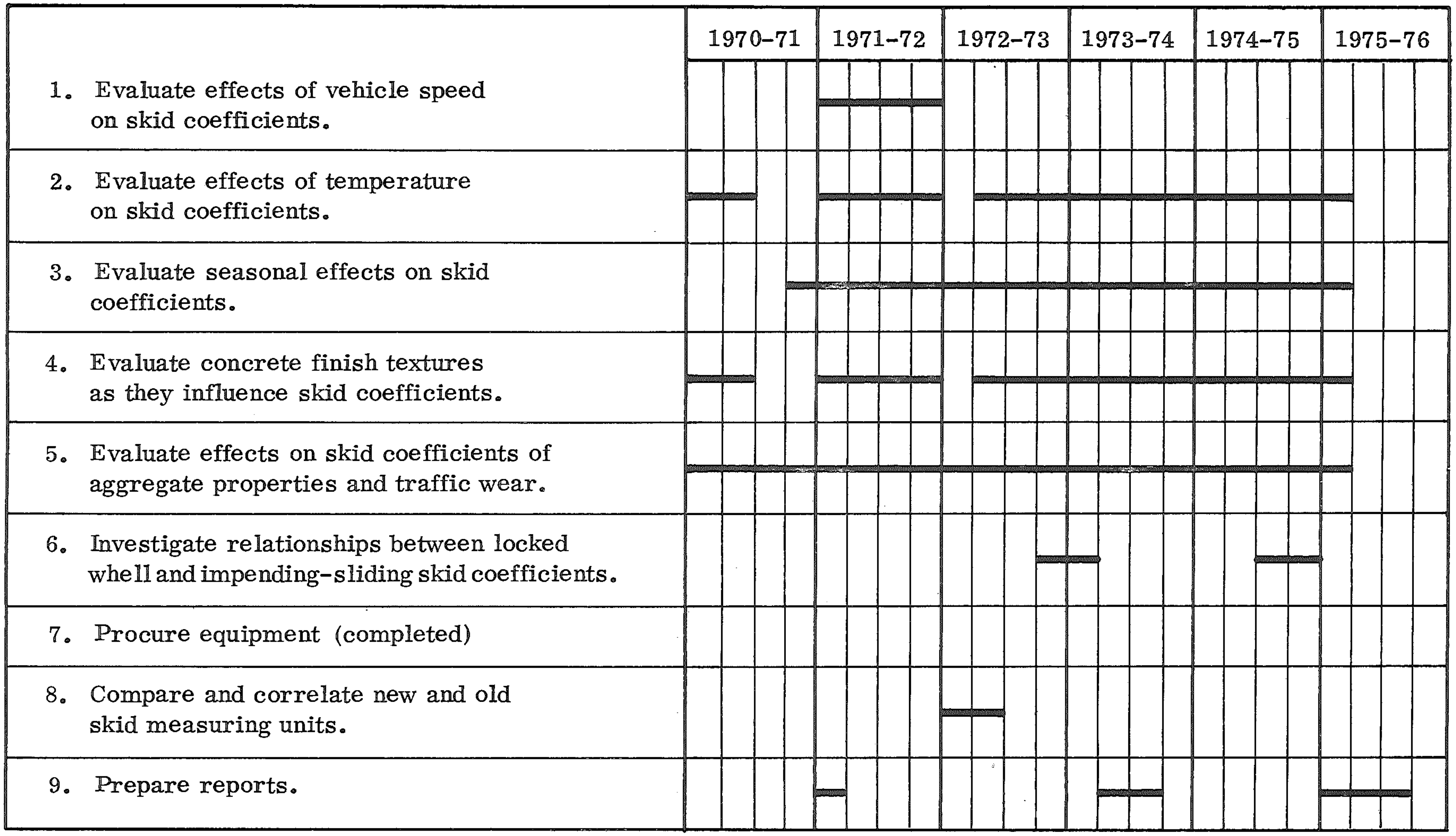


Figure 2. Proposed work schedule for Research Project 69 G-173.

APPENDIX A

MICHIGAN DEPARTMENT OF STATE HIGHWAYS
EQUIPMENT FOR MEASURING
PAVEMENT SKID RESISTANCE

Research Laboratory Section
Testing and Research Division
Research Project 54 G-74
Research Report No. R-747

Lansing, February 1971

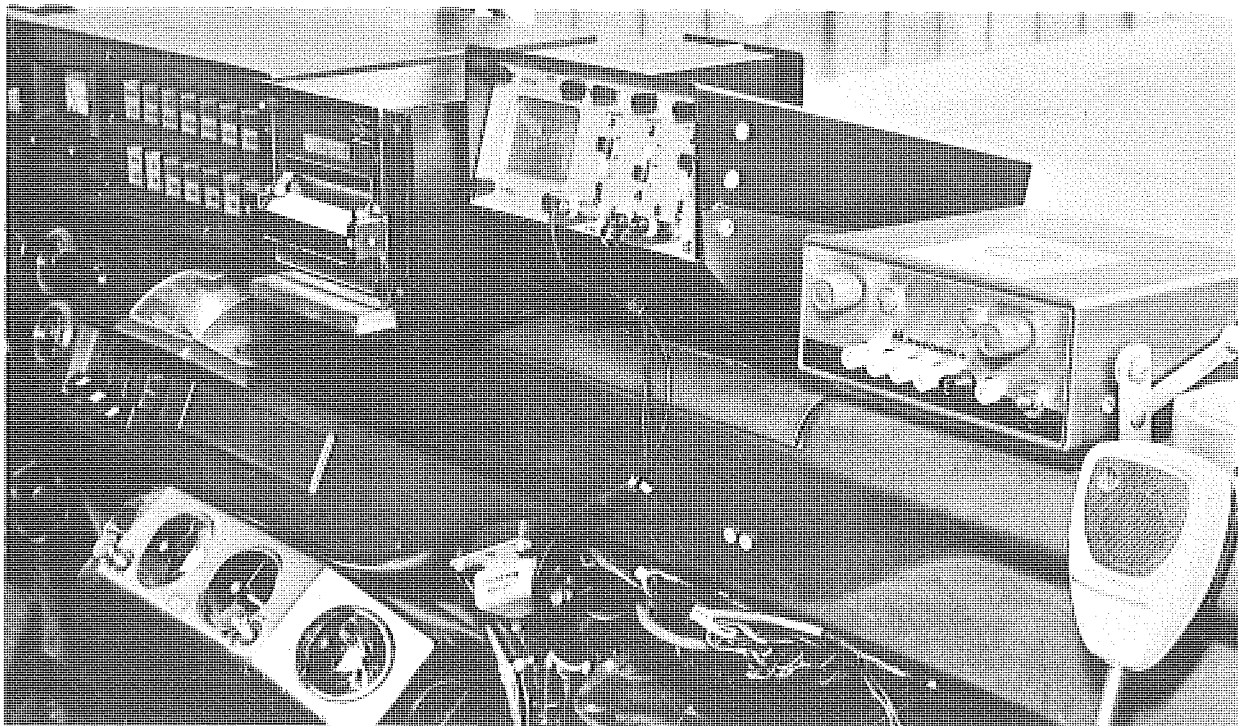
MICHIGAN DEPARTMENT OF STATE HIGHWAYS
EQUIPMENT FOR MEASURING
PAVEMENT SKID RESISTANCE

This report describes the equipment and procedures used by the Michigan Department of State Highways for determining the coefficient of wet sliding friction of pavement and bridge surfaces. The measuring system is of the self-contained, towed two-wheel trailer type (Fig. 1).

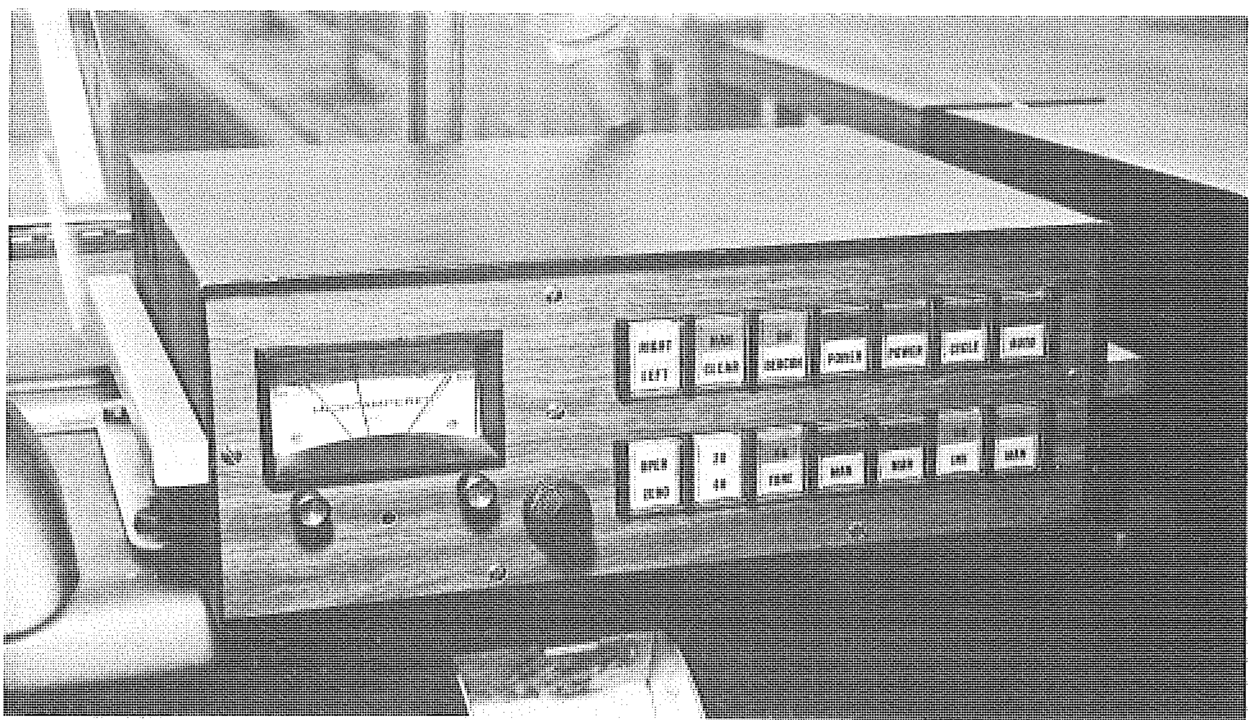
Figure 1. Tow vehicle and skid trailer.

Tow Vehicle

The tow vehicle currently in use (our fifth replacement) is a 1970 Chevrolet Tilt-Cab Model TE 51803 with a 97-in. wheelbase and a 366 cu in. V-8 engine. It is equipped with vacuum-assisted hydraulic brakes, hydraulic power steering, and Allison automatic transmission. Advantages of this vehicle include excellent sight distance from a relatively high cab, 360-degree visibility, short turning radius, and sufficient power to pull the trailer at a constant speed during tests.



Overall view showing (left to right) system controller, digital printer, monitor scope, and two-way radio.



System controller with tone-generating speed controller (20 or 40 mph set-point speed meter at left).

Figure 2. Dash-mounted control units.

A. Tow Vehicle Accessories

1. Body: special pickup type, 9 ft 6 in. by 7 ft 6 in. by 1 ft 6 in.

2. Water System: two tanks with combined capacity of 450 gal, jointed by a 2-in. equalization pipe and pressurized to a regulated 35 psi. Water is spilled from two 1-in. pipes, at a rate of 3.5 gal per test, in such a manner that it strikes the pavement surface at a 45-degree angle in the trailer wheel paths. Water release is controlled by normally closed, 12 vdc solenoid valves.

3. Power Supply - Compressor Unit: Externally mounted package powered by a 4 cycle, 12 hp engine (Kohler model K3015) driving a 12 cu ft air compressor (Quincy model 216) with 1690 cu in. air tank and a 60 amp Delco alternator with full transistor regulator and 12 vdc storage battery.

B. Instrumentation

1. System and Cycle Controller:

This shock-mounted unit in the center of the vehicle dashboard provides complete system control by either operator or driver. The controls (illuminated push button type) indicate modes and sequences of operation and provide system alarms. Figure 2 shows the layout of the units and a close-up view of the controller.

The following is a description of the switch and indicator functions.

(a) Right - Left wheel movement detector.

Two solid-state proximity switch amplifiers (Micro-Switch No. 20 FLI) mounted under the truck dash are connected to proximity switch sensors (Micro-Switch No. 204 FSI) mounted on each of the skid trailer wheel backing plates. A steel, ten-fingered disc connected to the moving wheel and positioned in close proximity to the sensors provides detection of any wheel movement greater than 36 degrees (Fig. 3). Activation occurs only when skid tests are being performed, at which time the sensor detection signal is presented to wheel movement logic circuitry in the controller. If movement is detected during the skid an alarm light will be actuated which identifies the slipping wheel.

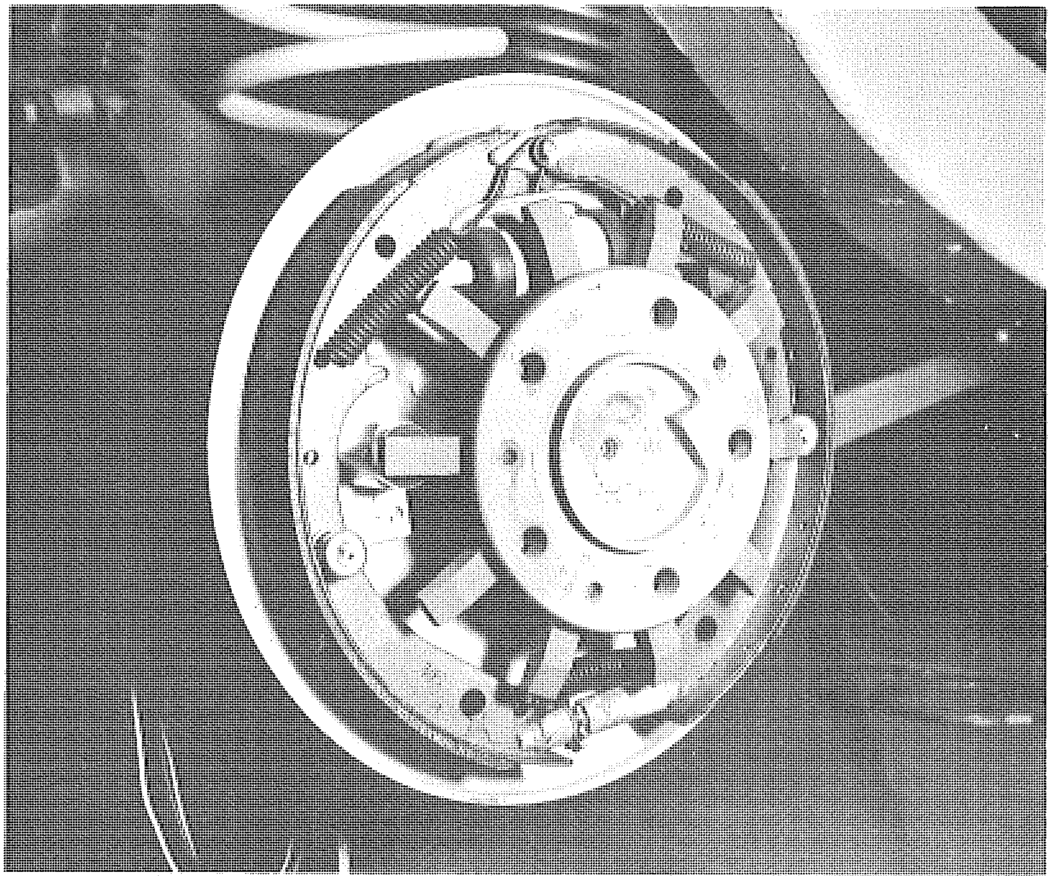


Figure 3. Skid trailer wheel showing proximity switch sensor.

Alarm indication will be held until such time as the Man Clear button is actuated or until the start of next skid cycle, at which time the alarm is automatically cleared.

(b) Beacon, Brake, and Water Power Controls

These push buttons control and confirm power application to the vehicle warning light and to the trailer brake and water solenoids. Also Man Brake and Man Water push button indicators are provided for system check out.

(c) Man On and Auto On Controls

The system operator may select either Man On or Auto On mode of operation by push button. In the Man On Mode all operations must be initiated by push button. In the Auto On mode a Cycle Start push button initiates an automatic cycle of operations--the water solenoids are activated, 0.7 seconds later brake solenoids are energized and power is held to both for an additional 1.9 seconds to complete the skid test cycle.

(d) Other Controls

The controller also includes switch indicators for 115 vac inverter and speed indicator operation. Speed is determined by a d-c tachometer generator attached to the truck drive train. Its output is compared to a stable push-button selected reference for speeds of 20 or 40 miles per hour. A visual null meter is also provided with the high and low set points to provide high and low speed audible alarms. The normal operation range of these set points is approximately $\pm$ 0.5 mph.

2. Digital Skid Coefficient Recording System:

This conditioning and recording system was designed to produce a digital printout, in engineering units, of pavement skid coefficients 0.2 seconds after a test completion. To retain the malfunction detection properties of analog format, a long-persistence monitor oscilloscope is included in the system. This enables the operator to view the complete analog signal which is being converted to a digital coefficient.

A typical 40 mph Michigan analog skid test record and timing cycle is shown in Figure 4.

A 20 mph record would be similar except that the breakaway amplitude would be less and the "start uniform sliding" point would fall to the left, or earlier in the cycle.

The function of the digital system is to sense the start of the skid cycle, then delay until the signal reaches the uniform sliding area. Then at that point (t_1) begin integrating the area under the curve and continue integration until point t_2 is reached. At that time the integrated mean voltage is converted to a digital signal and fed to the digital printer.

During the test period, the entire analog signal, including the t_1 and t_2 timing pulses, is displayed on the monitor screen.

Specifications for the system are attached.

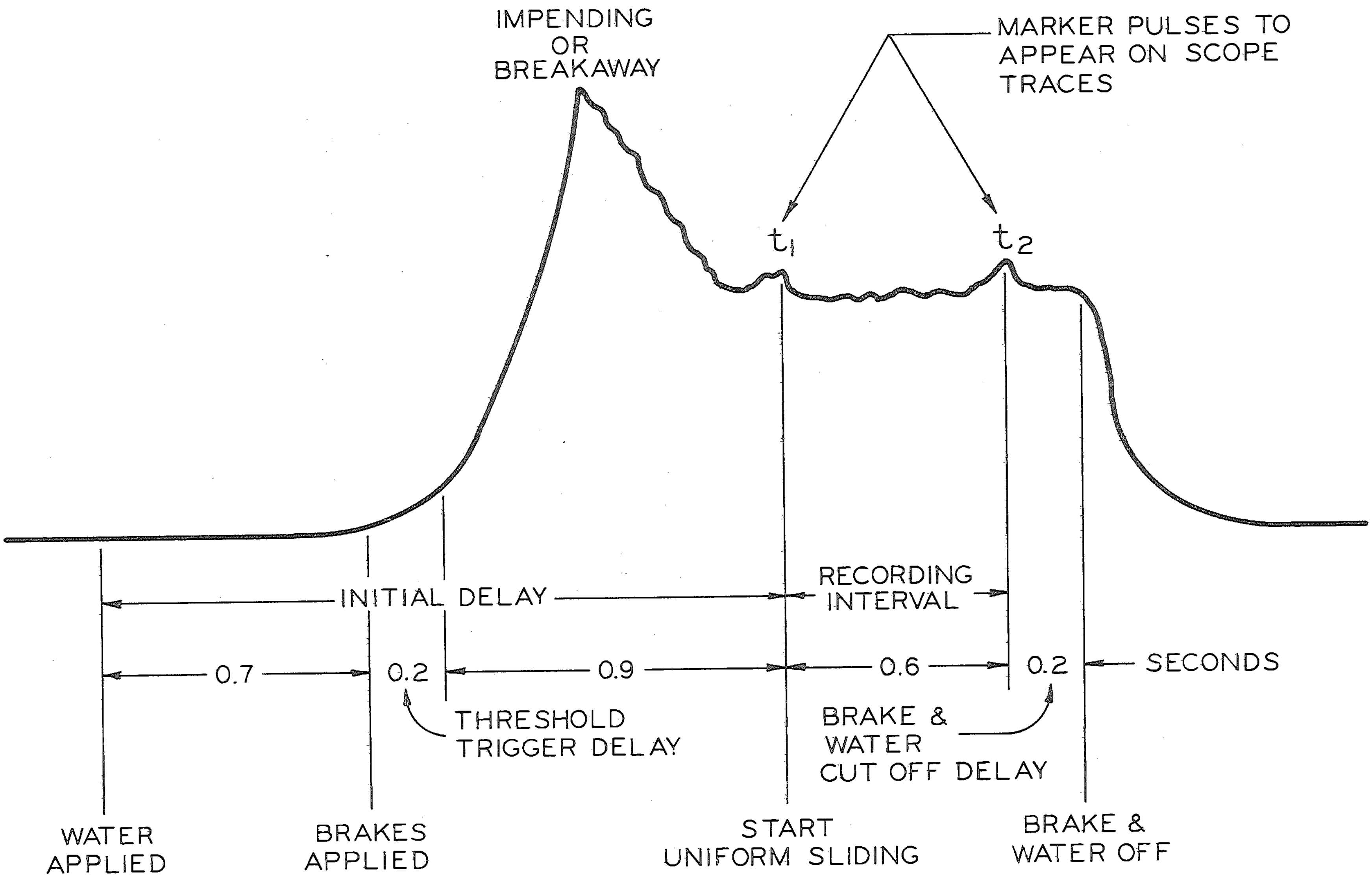


Figure 4. Typical 40 mph analog skid record and timing cycle.

Trailer

The trailer was originally constructed from a salvaged 1949 Buick frame, rear axle, and torque tube, with standard Buick braking system but has since been almost totally modified. Figure 5 shows the trailer without its sheet aluminum cover.

A. Trailer Specifications

1. Brake actuation system: 45-psi air pressure over hydraulic (1,500 psi) pressure, activated by 12 vdc solenoids (Fig. 6).

2. Wheel suspension: coil springs and spring/oil shock-strut damping (Fig. 7).

3. Tow hitch: oversized (house trailer type) ball-and-socket hitch located 10-3/4 inches above pavement and transversely midway between the wheels, 93.9-in. longitudinally forward of the trailer axle centerline.

4. Cover: aluminum sheet, riveted together in sections and removable in one piece.

5. Weight: 1,750-lb axle and 146-lb hitch. Weight is controlled and distributed by lead cast over the axle.

6. Tires: standard 7:50-14 tire as specified in ASTM Designation E 249-64 T. Tires are used only for testing. For en-route traveling, regular automotive tires are used to avoid excessive wear on the test tires.

B. Instrumentation

1. Torque tube. Two Micro Measurement 350-ohm No. Ed-DY-250BG-350 strain gages are mounted on top and bottom of the vertical axis of the torque tube, 4-1/2 in. forward of the rear torque tube shoulder (Fig. 8).

2. All cabling is selected to maintain high electrical insulation properties under conditions of dampness and water spray, particularly at strain gage connection points. Vibration and shock are controlled by use of clamps or shock mounts.

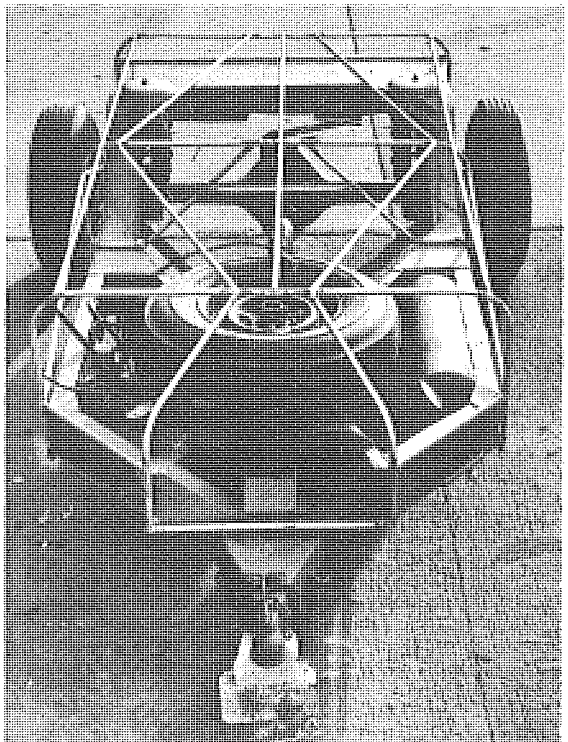
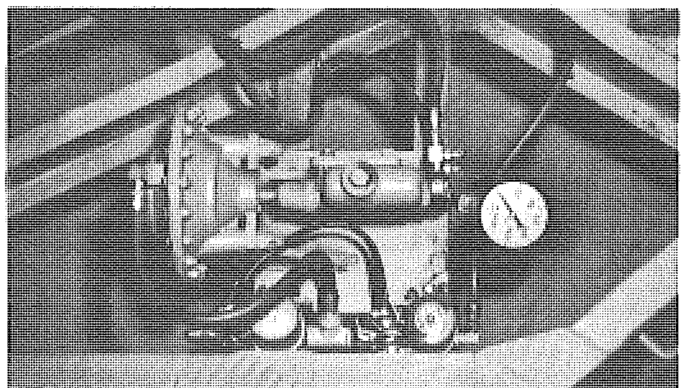


Figure 5. Skid trailer, shown during refurbishing with cover frame in place prior to mounting aluminum sheet cover.

Figure 6. Top view of brake actuation system, showing master cylinder, pressure diaphragm, control solenoids and pressure gage.



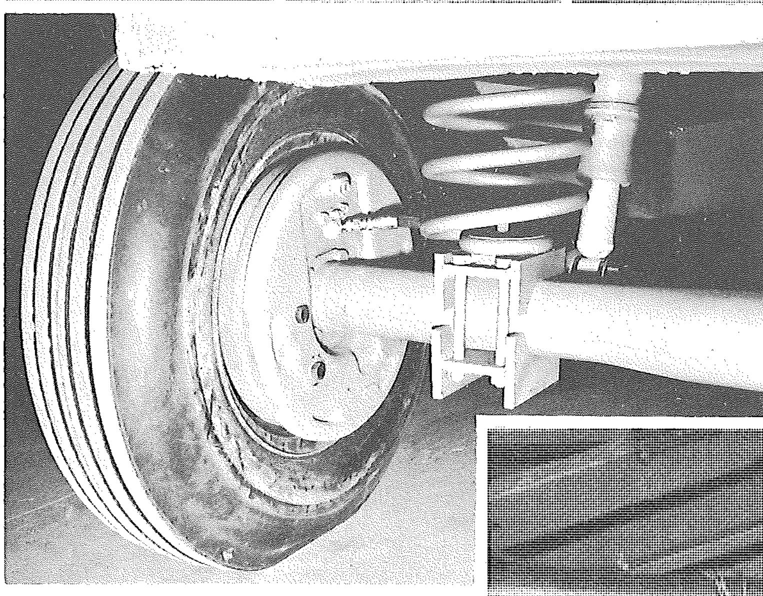
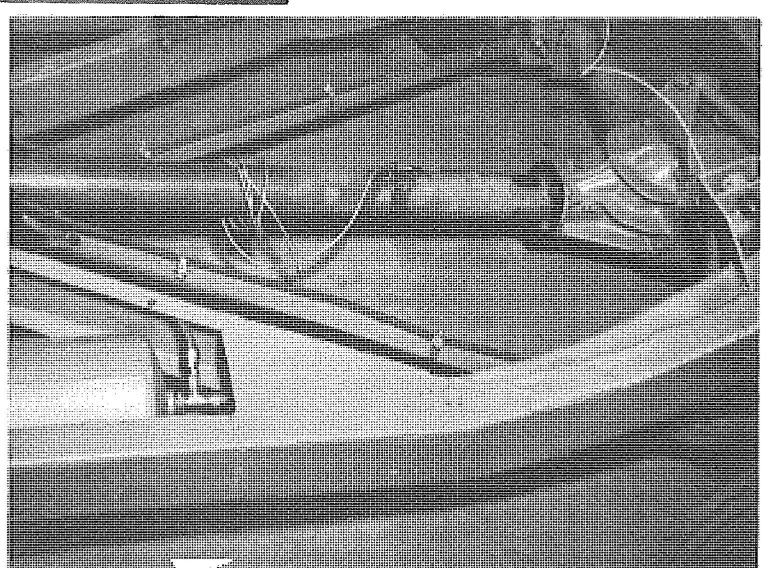


Figure 7. Test tire and trailer wheel suspension system.

Figure 8. Torque tube, showing strain gage mounting area.



Calibration

A. Equipment

1. Laboratory strain sensing and recording equipment
2. Calibrating platform with skid-resistant pads
3. Two (series-wired) load cells with connecting rods
4. Loading bar and supports
5. Loading chains and equalizing bar
6. Loading cylinder and mount
7. Electrically controlled hydraulic pump

B. Procedure

1. Anchor loading cylinder securely to floor
2. Position loading platform appropriate distance (gaged by length of loading chains) from, and centered upon, loading cylinder.
3. Place load cells with connecting rods between loading bar and skid-resistant pads of calibrating platform.
4. Secure loading chains to loading bar in such a manner that loading cylinder throw is sufficient to allow adequate movement of skid-resistant pads. Adjustment can be made by shortening or lengthening chain links.
5. Connect hydraulic pump to loading cylinder.
6. Place trailer in position on skid-resistant pads of loading platform making certain trailer is properly aligned (tires parallel to direction of applied load) and level.
7. Connect torque tube strain gage lead and calibration load cell leads to recording equipment.

8. Proceed with desired calibrating measurements by locking truck and trailer brakes and applying a uniform rate of loading with hydraulic pump until trailer tires slide on skid-resistant pads. Repeat loading procedure until at least three successive similar traces are recorded.

9. Following loading procedure, a calibration load equivalent must be recorded for the balance resistor (560 K) to determine an equivalent coefficient of friction for "black box" balance gain adjustment and printout.

10. Determine the relationship between load cell output (lbs) and torque tube output by taking a reasonable number of simultaneous points from each recorded trace. Use this relationship to establish the drag force in pounds represented by each increment of torque tube output.

11. Complete calibration by determining torque tube output (drag force) representing various values of μ in the following equation:

$$\mu = \frac{Fd}{Fn - Fd \dfrac{h}{Lw}}$$

where:

μ = Coefficient of sliding friction

Fd = drag force

Fn = normal force

h = height of center of hitch ball above ground level in inches.

Lw = horizontal distance from hitch ball centerline to trailer axle centerline in inches.

12. Using the same equation, compute equivalent μ value for the balance resistor and adjust "black box" gain to produce required digital print out. Figure 9 shows the system calibration set-up.

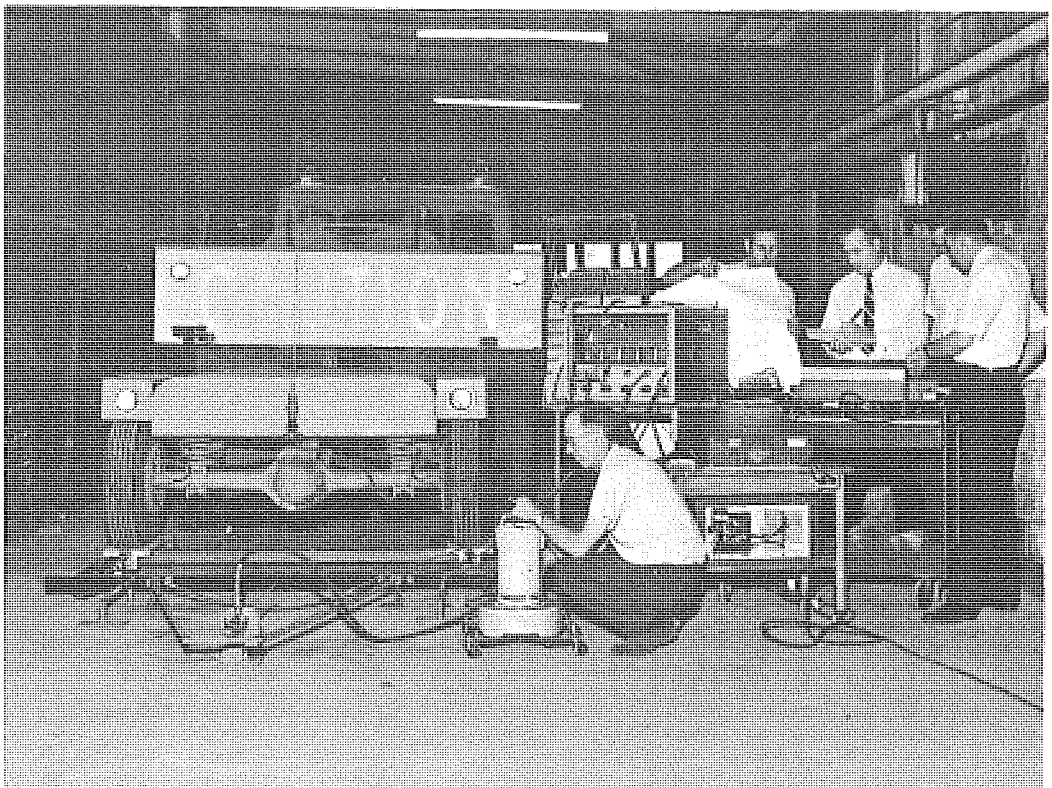


Figure 9. Calibration of skid system.

Determination of Valid Skid Coefficients

A. Field Testing Procedure

1. Speed is determined by the testing situation. For intersections and short test runs, a 20 mph speed is used; for open areas, 40 mph. Speed measurement control is calibrated at 20 and 40 mph. At other speeds it is necessary to use the backup speed-indicating instrumentation. All data are reported as 40 mph wet sliding friction values. Conversions from 20 mph are based on conversion factors determined experimentally from 10, 20, 30, and 40 mph skid tests on both concrete and bituminous pavements.

2. At intersections, conduct at least three tests in the last 200 ft of each lane (the "stopping area") in such a manner that the same pavement is not included in more than one test. (For example, divide the last 200 ft into thirds and conduct one test in each third.)

3. At other locations, determine the minimum number of randomly selected tests from the following table:

Usable Length (miles)	Minimum Tests per lane
0-3	3
3-4	4
4-5	5
5-6	6
6-7	7
7-8	8
8-9	9
9-10	10

Drive over each project prior to testing in order to determine the amount of usable mileage available.

B. Verification of Test Results

The following table established the degree of variation with a given test series that is acceptable without the necessity of additional tests:

UPPER CONTROL LIMITS FOR SKID COEFFICIENT RANGES

Probability of Exceeding Range	Average Skid Coefficient	Number of Samples*									
		3	4	5	6	7	8	9	10	11	12
0.050	0.0 - 0.19	.048	.051	.053	.055	.059	.062	.064	.064	.066	.068
0.025	0.20 - 0.33	.058	.062	.064	.067	.067	.069	.071	.074	.074	.076
0.010	0.34 - 0.46	.065	.067	.072	.074	.077	.077	.079	.081	.081	.084
0.005	0.47 - 0.52	.072	.074	.077	.077	.079	.081	.081	.084	.084	.086
	0.53 - 0.65	.083	.085	.087	.089	.091	.091	.093	.095	.095	.097

* Values in the "Number of Samples" columns are expressed in coefficients of friction (μ) and indicate the maximum allowable differences between highest and lowest readings--in other words, the ranges.

1. If a series of tests (S_1) exceeds the maximum acceptable degree of variation, or upper control limit, run the following checks:

   a. Check for a physical explanation in the surface tested. If an area of surface difference can be established, it should be tested separately.

b. Check for malfunction of equipment. If found, note and correct, and re-run all tests affected.

c. If neither a surface difference nor equipment malfunction is indicated, repeat the test that produced the "out-of-control" range (this will usually be one of the three tests run and will be obvious in that its value will be significantly different from the other two). If the significantly different value is verified as correct, run a complete second test series (S_2), using particular care to test different areas from those tested in S_1. If the significantly different value is not verified as correct, conduct at least two more tests in the same location and use the average of the second test plus these two to replace the aberrant S_1 point.

NOTE: The above sampling and verification plan is designed such that greater precision is required in the lower, more critical, coefficient range.

Field Test Records

The following items of project information are to be recorded in the field for each project tested.

A. Date

B. Temperatures (pavement and air)

C. Location and project number

D. Test number with digital skid coefficient

E. Tire pressure and tread depth

F. Intersection diagram (to be attached to field test record form)

G. Test speed and surface type

H. The following factors are known to effect skid resistance measurements and therefore should be controlled if possible. If they are not amenable to control their existence in a test project should be recorded:

1. Test speed

   a. magnitude

   b. variation during test

2. <u>Test tires</u>

    a. wear

    b. pressure

    c. temperature

3. <u>Pavement surface wetting</u>

4. <u>Brakes: ability to keep wheels locked when braking</u>

5. <u>Geometric factors</u>

    a. grade

    b. traffic or passing lane

    c. lateral placement in lane

    d. crown

6. <u>Surface factors</u>

    a. oil drippings

    b. soil, sand, or silt

    c. painted traffic stripes

    d. roughness

    e. bleeding

    f. faulted joints

    g. joint seal extruded or recessed

    h. temperature

SPECIFICATIONS FOR
AUTOMATIC, TRANSISTORIZED DIGITAL OUTPUT SYSTEM
FOR PAVEMENT SKID MEASURING EQUIPMENT

Input:	Half bridge, 350-ohm gage (customer supplied).
Bridge Completion Resistors:	Built in.
Balance Control:	Front panel, screwdriver adjust (coarse) and locking knob (fine).
Calibration:	Built in, front panel switchable resistor.
Bridge Excitation:	10 volt dc.
Gain Control:	Front panel, screwdriver adjust.
Test Control:	A test push button provided which simulates a trigger point to be utilized during calibration.
Outputs:	(a) A 3-in. monitor osciloscope with P-7 long persistence CRT, triggered by the start of strain gage bridge output and giving a single sweep for each test. Sweep speed 0.5 to 2.5 sec (3.0 to 15 cm/sec) and vert, amp, as required. (b) Marker pulses to be added to the bridge output at the beginning and end of recording interval for display on monitor CRT only. (c) A three digit printout, in skid coefficient units accurate to 1 percent. This printout is the result of digitizing the integrated value of the bridge output during the indicated recording interval. Filtering to remove the effects of superimposed ripple and noise is used only at the CRT monitor.

Initial Delay and Recording Interval: System provides for two operating positions, each having independent initial delay, integrating time and gain control. Internal screwdriver controls to permit the adjustment of both the initial delay and recording interval over the range of 0.1 to 1 second.

System Trigger: Internal screwdriver threshold adjustment which automatically initiates the test cycle by sensing bridge output signal.

Power All power to be provided by a 12-vdc to 115-vac, 60 cps inverter or as required. Source current from battery not to exceed 18 amps.

Mounting: (a) Monitor oscilloscope and printer mounted as a single remote unit with shock mounts and provided with interconnecting cable, 8 ft long.

(b) The system electronics package should not exceed 19 in. wide by 10 in. x 12 in. deep, also being shock-mounted.

(c) Inverter shock-mounted with connecting cables for remote mounting up to 10 ft from electronics package.

Temperature: All silicone semi-conductors are to be used in system electronics including scope, printer, and inverter to permit storage up to at least 75 C and operation up to 60 C.

Accuracy: System accuracy of 2 percent over a temperature range of 0 C to 60 C and with line voltage changes of $\pm$10 percent.

Miscellaneous:

Interconnection Wiring:	All interconnecting cable between system packages is to be provided including mating connectors. The shielded wiring between the strain gage bridge and electronics package will be supplied by customer.
Manuals:	Two instruction and service manuals are to be included. These manuals are to include system block design, schematics, trouble-shooting voltage and signal test point information, description of the system operation, and the location of component parts and circuit cards. Also, replacement parts list.
Extender Cords:	An extender cord is to be supplied to facilitate maintenance on circuit boards.
Warranty:	This system will be guaranteed for all failures and out of specification performance, except abuse, for a period of one year. Any faulty items will be returned to supplier for repair or replacement at no cost to customer.
Source:	Michigan's Digital Output System Information Instruments, Inc. 62 Enterprise Drive Ann Arbor, Michigan 48106 (Approximate cost - $5,800.00)

APPENDIX B

MDSH REPORT NO. 249
TESTING AND RESEARCH DIVISION

SUMMARIES OF MICHIGAN PAVEMENT SKID RESISTANCE 1970 TEST PROGRAM

Research Laboratory Section
Testing and Research Division
Research Project 54 G-74
Research Report No. R-776

Lansing, August 1971

CONTENTS

LEGEND

Direction of Test Vehicle

NB, SB, EB, WB etc. = Northbound, Southbound etc.

Lane Tested (noted following direction of test vehicle)

RT = right turn lane

OL = outer lane (traffic lane)

CL = center lane

IL = inner lane (passing lane)

LT = left turn lane

D = deceleration lane

3 or 2 = third or second lane from centerline or median

SUMMARIES OF MICHIGAN PAVEMENT SKID RESISTANCE 1970 TEST PROGRAM

INTRODUCTION

During the 1970 calendar year, over 6,500 skid tests were conducted throughout Michigan. These tests are summarized in this report according to the annual reporting procedure initiated in 1965. Skid levels for five basic categories are included:

I Conventional Concrete and Bituminous Pavements

II Pavements After Five Years of Service

III Experimental Pavement Surfaces

IV High-Accident Locations

V Special Request Tests

Explanatory remarks are presented at the beginning of each category of tabulated data. All High-Accident Location tests and Special Request tests have been previously reported to interested agencies within the Department.

All skid test values are expressed as 40-mph coefficients of wet sliding friction (wsf). A wsf value of 0.40 is generally considered the dividing point between "satisfactory" and "unsatisfactory" pavement surfaces and this has been arbitrarily defined as the Departmental Safety Standard. Surfaces with coefficient values of 0.35 to 0.40 are in a "transitional" or "questionable" range. Projects below 0.35 could be dangerous under wet conditions, depending on prevailing speeds, road alignment, and geometrics. Surfaces with coefficients of 0.20 or less are as slippery as packed snow.[1] Reference should be made to Research Report No. R-585 ("Summaries of Michigan Pavement Skid Resistance: 1965 Test Program") and Research Report No. R-747 ("MDSH Equipment for Measuring Pavement Skid Resistance," February 1971) for information regarding operation of the skid-test device, selection of test areas, and verification of retests.

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[1] Moyer, Ralph A., "A Review of the Variables Affecting Pavement Slipperiness," Proceedings of First International Skid Prevention Conference, 1959.

SECTION I

CONVENTIONAL CONCRETE AND BITUMINOUS PAVEMENTS

CONVENTIONAL CONCRETE AND BITUMINOUS PAVEMENTS

Section I summarizes skid tests representing over 1,100 lane miles of trunkline surfaces tested during 1970.

Table 1— Concrete Pavements Constructed in 1969 and 1970

1969 Construction

Initial skid tests were conducted on 113.124 lane miles of concrete pavement after a one-year service period. Wet sliding friction (wsf) values ranged from 0.21 to 0.65 and averaged 0.48. Fourteen of the 71 lanes, representing 14.6 percent of the total lane mileage tested, yielded average wsf values below the Departmental Safety Standard of 0.40. All four lanes of Project M 23072-004, M 100 south of the Grand River in Grand Ledge, had friction levels of 0.34 or lower.

1970 Construction

During the initial service year, 24 lanes of concrete (79.838 lane miles) were tested. Coefficients ranged from 0.37 to 0.64 and averaged 0.54. The only lane which had an average wsf value below 0.40 was the NB#2 lane of US 24 near 15 Mile Rd (Project Ms 63031-020). This lane represents 1.6 percent of the lane mileage tested.

Table 2— Bituminous Concrete (4.12) Constructed in 1969 and 1970

1969 Construction

After a one-year service period, 122.354 lane miles of bituminous concrete were tested. Friction levels ranged from 0.30 to 0.64 and averaged 0.47. Four of the 46 lanes tested (2.1 percent of the total mileage) were below the Departmental Safety Standard. All four of these lanes were on Project Mb 12021-006.

1970 Construction

Initial service-year skid tests were conducted on 444.002 lane miles of bituminous concrete during test year 1970. Only one lane, on Project Mb 67051-002, located on M 115 northwest of M 66, yielded a friction level below 0.40. This particular lane had an average wsf value of 0.39 and represents only 2.2 percent of the 1970 construction bituminous concrete tested this year.

Table 3— Bituminous Aggregate (4.11) Constructed in 1969 and 1970

1969 Construction

Skid tests were performed after a one-year service period on 72.700 lane miles of bituminous aggregate. The 12 lanes tested yielded coefficients ranging from 0.36 to 0.70 and averaging 0.53. None of the lanes had average wsf values below 0.40.

1970 Construction

During the initial year of service, 40 lanes (220.642 lane miles) of bituminous aggregate surface course 4.11 were skid tested in 1970. Fifteen of the forty lanes, representing 12.4 percent of the lane miles tested, yielded average wsf values below the Departmental Safety Standard. Additional testing of low friction lanes was conducted on 11 of the 15 lanes and the updated wsf values reported as special requests 4, 6, 7, 8, and 13 (Table 27). Wsf values on four of the 11 lanes retested improved enough to exceed the 0.40 mark.

Table 4— Miscellaneous Bituminous Surfaces Constructed in 1969 and 1970

NON-SKID SURFACE TREATMENT

1969 Construction

Only one NSST project (5.6 lane miles) was tested this year. Coefficients ranged from 0.53 to 0.59 after a one-year service period, and averaged 0.56.

STONE-FILLED SAND-ASPHALT AND SIMILAR SURFACES

1969 Construction

Wet sliding friction coefficients were determined on four stone-filled sand-asphalt surfaces during their first service year. Coefficients ranged from 0.28 to 0.69 and averaged 0.48. Six of the 16 lanes tested, 13.5 percent of the lane miles, yielded average wsf values below 0.40. All six lanes were on US 24 (Telegraph Rd) at Warren Rd, Project Ms 82053-045.

1970 Construction

All 12 lanes of stone-filled sand-asphalt checked in 1970, during the initial service year, had average wsf values above the Departmental Safety Standard. Coefficients ranged from 0.40 to 0.64 and averaged 0.52 on the 86.002 lane miles tested.

Table 5— Conventional Concrete and Bituminous Pavement Summary

During test year 1970, the average of the average coefficients for each surface type was above the Departmental Safety Standard. Outstanding friction level characteristics (coefficients of 0.50 or higher) were determined for initial year concrete, one-year bituminous aggregate, one-year non-skid surface treatment, and initial year stone-filled sand-asphalt.

TABLE 1
CONCRETE PAVEMENTS CONSTRUCTED IN 1969 and 1970

1969

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
U 11031-004	M 139 from I 94 N'ly to Ox Creek and Pennsylvania Central RR	Carl Goodwin & Sons, Inc.	75-5	14-45	NBOL	0.30	0.34	0.31
					NBIL	0.38	0.40	0.39
					SBOL	0.44	0.48	0.46
					SBIL	0.33	0.37	0.36
M 23072-004	M 100 from N of Franklin St N intermittently to a point 600-ft NE of the Grand River	Kegle Construction Co.	19-18	19-18	NBOL	0.31	0.38	0.34
					NBIL	0.31	0.36	0.34
					SBOL	0.30	0.38	0.34
					SBIL	0.21	0.30	0.26
F 25042-015	M 78 relocation from E of Bristol Rd E'ly to W City Limits of Flint	Cooke Contracting Co.	63-54	63-54	EBOL	0.52	0.54	0.53
					EBCL	0.48	0.53	0.51
					EBIL	0.59	0.61	0.60
					WBOL	0.41	0.46	0.44
					WBCL	0.42	0.46	0.44
					WBIL	0.53	0.56	0.55
F 25084-015	M 78 from approximately 500-ft W of Howe Rd E'ly to Vassar Rd	Denton Construction Co.	63-56 & 63-54	63-56 & 63-54	EBOL	0.51	0.53	0.52
					EBCL	0.49	0.51	0.50
					EBIL	0.48	0.52	0.50
					WBOL	0.55	0.57	0.56
					WBCL	0.54	0.60	0.56
					WBIL	0.59	0.64	0.62
F 25084-016 (part)[1]	M 78 (extended) from Vassar Rd E to M 15 (Station 888+00 to 933+63 Only)	Denton Construction Co.	63-54	63-54	EBOL	0.46	0.49	0.47
					EBCL	0.52	0.54	0.53
					EBIL	0.54	0.58	0.56
					WBOL	0.42	0.44	0.43
					WBCL	0.51	0.55	0.52
					WBIL	0.54	0.59	0.56
F 25084-016 (part)[2]	M 78 (extended) from Vassar Rd E to M 15 (Station 933+63 to 1078+00 Only)	Sargent Construction Co.	63-56	63-56	EBOL	0.41	0.44	0.43
					EBIL	0.49	0.55	0.52
					WBOL	0.40	0.42	0.41
					WBIL	0.46	0.50	0.47
SS 25101-012	M 57 from E City Limits of Clio E'ly to M 54	W. F. McNally Co.	17-66	25-8	EBOL	0.36	0.41	0.38
					EBIL	0.40	0.44	0.42
					WBOL	0.36	0.42	0.38
					WBIL	0.38	0.44	0.40

(1) Conventional paver used.

(2) Slip-form paver used.

TABLE 1 (Cont.)
CONCRETE PAVEMENTS CONSTRUCTED IN 1969 and 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
U 31051-014	US 41 relocation from 280-ft W of Division St W'ly to 270-ft W of Pearl St, City of Houghton	Proksch Construction Co.	31-45	31-45	NBOL	0.44	0.47	0.45
					NBIL	0.49	0.51	0.50
					SBOL	0.50	0.53	0.52
					SBIL	0.49	0.50	0.49
U 38083-017	I 94 BL - US 27 BR - M 50 (Michigan Ave) from W of Lydia St NE'ly to W of intersection of Clinton St & Jackson St	Denton Construction Co.	30-35	30-35	EBOL	0.37	0.40	0.38
					EBCL	0.39	0.43	0.41
					EBIL	0.38	0.43	0.41
					WBOL	0.33	0.41	0.37
					WBCL	0.39	0.42	0.40
					WBIL	0.41	0.43	0.42
F 41132-022[3]	US 131 from S of 10 Mile Rd N to Station 925+00	L. W. Edison	41-46 & 41-48	41-46	NBOL	0.55	0.60	0.57
					NBIL	0.54	0.56	0.55
					SBOL	0.57	0.60	0.59
					SBIL	0.52	0.57	0.55
F 41132-022	US 131 from Station 925-00 N to 14 Mile Rd	Carl Goodwin & Sons, Inc.	41-46 & 41-48	41-46	NBOL	0.42	0.45	0.44
					NBIL	0.58	0.64	0.61
					SBOL	0.41	0.44	0.43
					SBIL	0.60	0.63	0.61
I 73101-022	I 675 from I 75 W'ly to Saginaw City Limits	Sargent Construction Co.	71-47	79-73	EBOL	0.42	0.45	0.43
					EBIL	0.52	0.56	0.53
					WBOL	0.48	0.51	0.50
					WBIL	0.47	0.53	0.50
F 73131-001	M 83 from 300-ft N of Townline Rd NW'ly to 488-ft N of N City Limits of Frankenmuth omitting from 800-ft N of Cass River Bridge N to Genesee St	Titus Construction Co.	17-66	63-54	NBOL	0.27	0.53	0.41
					NBIL	0.33	0.41	0.37
					SBOL	0.29	0.43	0.35
					SBIL	0.37	0.41	0.39
U 82081-021	M 153 (Ford Rd) from 620-ft E of M 39 (Southfield Rd) E'ly to 600-ft W of Greenfield Rd	T. Angelo Cement Const. Co.	E. C. Levy (Dix)	63-7	EBOL	0.48	0.50	0.49
					EB#3	0.38	0.44	0.40
					EB#2	0.41	0.44	0.42
					EBIL	0.48	0.52	0.50

(3) Skid tests were conducted and reported with 1969 test year data.

1969 CONT.

TABLE 1 (Cont.)

CONCRETE PAVEMENTS CONSTRUCTED IN 1969 and 1970

Year	Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
				Coarse	Fine		Low	High	Avg
1969 CONT.	BU 82104-023 BI 82252-185	On Davison Freeway from Goddard to Charest	Cooke Contracting Co.	E. C. Levy (Dix)	63-7 & 63-55	EBOL EB#3 EB#2 EBIL WBOL WBCL WBIL	0.59 0.57 0.57 0.59 0.55 0.60 0.57	0.64 0.65 0.60 0.62 0.58 0.62 0.64	0.61 0.61 0.58 0.60 0.56 0.61 0.61
1970	F 32092-004 (1)	US 25 from M 53 E'ly to Huron City	Sargent Construction Co.	32-4	79-73	EB WB	0.52 0.57	0.56 0.59	0.54 0.58
	F 44043-001 (1)	M 78 relocation from Genesee-Lapeer Co. Line (Washburn Rd) E'ly to 1253-ft E of Golf Rd	L. W. Edison Co.	63-4	63-4	EBOL EBIL WBOL WBIL	0.58 0.58 0.59 0.58	0.64 0.60 0.62 0.62	0.60 0.59 0.60 0.60
	Ms 63031-020	US 24 (Telegraph Rd) from approximately 1400-ft N of 14 Mile Rd N'ly to approximately 2670-ft N of 15 Mile Rd (Maple Rd)	Anderson & Ruzzin, Inc.	E. C. Levy (Dix)	63-55	NBOL NB#3 NB#2 NBIL SBOL SB#3 SB#2 SBIL	0.46 0.43 0.37 0.45 0.48 0.46 0.47 0.53	0.50 0.47 0.40 0.48 0.53 0.48 0.55 0.56	0.48 0.44 0.39 0.47 0.51 0.47 0.51 0.54
	F 65033-001	I 75 BL from Cooke Rd, at I 75 interchange, NE'ly to M 76	Eisenhour Construction Co.	65-7	65-7	NB SB	0.58 0.57	0.62 0.60	0.60 0.58
	I 65041-002 (1)	I 75 from S Ogemaw Co. Line NW'ly to SE of Cooke Rd	Eisenhour Construction Co.	65-7	65-7	NBOL NBIL SBOL SBIL	0.52 0.58 0.65 0.60	0.56 0.61 0.68 0.64	0.54 0.59 0.66 0.62
	Mtb 82144-018	M 29 from Sunningdale Ave E'ly to E Limits of Grosse Pointe Woods	T. Angelo Cement Const. Co.	E. C. Levy (Dix)	63-88	EBOL EBIL WBOL WBIL	0.56 0.51 0.40 0.40	0.58 0.56 0.44 0.46	0.57 0.54 0.42 0.43

(1) Slip-form paver used.

TABLE 2

BITUMINOUS CONCRETE (4.12) CONSTRUCTED IN 1969 and 1970

1969

Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
Mb 04032-007	US 23 from State Rd to Bridge over Thunder Bay River	Alpena Paving Co.	79-21	04-29	NB	0.54	0.55	0.55
					SB	0.55	0.56	0.56
Mb 12021-006	US 12 from Wright St to Avery Dr., City of Coldwater	John Yerington Co.	Material Services Corp. Chicago, Ill.	12-35	EBOL	0.36	0.37	0.37
					EBIL	0.36	0.37	0.37
					WBOL	0.30	0.32	0.31
					WBIL	0.36	0.37	0.37
Ms 25072-011	M 21 - M 54 (Dort Hwy) from 521-ft S of M 21 (Court St) N'ly to 100-ft N of M 21 (Davison Rd)	Flint Asphalt & Paving Co.	47-3	63-54	NBOL	0.39	0.42	0.40
					NBIL	0.42	0.44	0.43
					SBOL	0.41	0.42	0.41
					SBIL	0.46	0.46	0.46
Mb 25072-013	M 54 (Dort Hwy) from Carpenter Rd N'ly to 510-ft N of Mt. Morris Rd omitting 1185-ft at Carpenter Rd	Spartan Asphalt Paving Co.	47-3	63-54	NBOL	0.49	0.53	0.50
					NBIL	0.58	0.59	0.58
					SBOL	0.49	0.53	0.51
					SBIL	0.57	0.60	0.59
U 41012-006	US 131 (Plainfield Ave) from I 96 NE'ly to Airway St, City of Grand Rapids	Rieth-Riley Const. Co., Inc.	41-46	41-113	NBOL	0.53	0.56	0.55
					NBIL	0.61	0.64	0.62
					SBOL	0.53	0.56	0.55
					SBIL	0.55	0.58	0.57
F 41122-006	M 57 from US 131 relocation E'ly to Teft Ave	Rieth-Riley Const. Co., Inc.	41-46	41-113	EB	0.54	0.58	0.56
					WB	0.55	0.58	0.57
Mtb 50071-008	M 29 from N to S City Limits of St. Clair Shores	Cooke Contracting Co.	50-35	50-35	NBOL	0.41	0.43	0.42
					NBIL	0.46	0.50	0.48
					SBOL	0.40	0.45	0.43
					SBIL	0.47	0.49	0.48
Ms 61022-006	M 46 (Miller Ave & Apple Ave) from US 31 BR (Muskegon Ave) E'ly to Getty St, City of Muskegon	Rieth-Riley Const. Co., Inc.	70-9	70-9	EBOL	0.56	0.58	0.57
					EBIL	0.55	0.59	0.58
					WBOL	0.55	0.56	0.55
					WBIL	0.59	0.60	0.59
Mb 63051-031 Ms 63051-032	US 10 (Woodward Ave) from 290-ft SE of I 75 BL (Square Lake Rd) SE'ly to 75-ft SE of Oakland Ave	Ajax Asphalt Paving, Inc.	63-4	63-4	SBOL	0.42	0.47	0.45
					SB#3	0.44	0.48	0.46
					SB#2	0.53	0.55	0.54
					SBIL	0.54	0.58	0.57

TABLE 2 (Cont.)

BITUMINOUS CONCRETE (4.12) CONSTRUCTED IN 1969 and 1970

Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
1969 CONT.								
Mtb 77022-009	Old M 21 from 80-ft W of 24th St E'ly to US 25 (Military St)	Blue Water Asphalt Co., Inc.	75-5	74-4	EBOL EBIL WBOL WBIL	0.40 0.43 0.41 0.41	0.44 0.44 0.45 0.45	0.43 0.43 0.43 0.42
Mb 78021-001	US 12 from Mann Rd E'ly to 200-ft E of Penn Central RR Crossing, omitting from US 131 E'ly to 430-ft E of E Village Limits of White Pigeon	Rieth-Riley Const. Co., Inc.	39-1	78-25	EB WB	0.44 0.46	0.52 0.52	0.48 0.50
U 82081-021	M 153 (Ford Rd) from 620-ft E of M 39 (Southfield Rd) E'ly to 600-ft W of Greenfield Rd	Cooke Contracting Co.	50-35	50-35	WBOL WB#3 WB#2 WBIL	0.59 0.54 0.56 0.57	0.62 0.58 0.59 0.60	0.60 0.55 0.58 0.59
Mtb 82144-017	M 29 from E City Limits of Grosse Pointe Woods SE'ly on M 29 (Vernier Rd) & NE'ly & NW'ly on M 29 (Lake Shore Rd) to E City Limits of St. Clair Shores	Cooke Contracting Co.	50-35 & 63-4	50-35 & 63-4	NBOL NBIL SBOL SBIL	0.50 0.55 0.49 0.52	0.52 0.59 0.55 0.54	0.51 0.57 0.52 0.53
1970								
RF 01051-001	US 23 from Iosco-Alcona Co. Line N'ly to N of the S Limits of Harrisville	Central Paving Co.	71-15	71-15	NB SB	0.53 0.54	0.56 0.56	0.54 0.55
Mb 03072-006	M 40 from Sherman St in City of Allegan NW'ly to City Limits of Holland, omitting from 125th Ave to 136th Ave and from 3715-ft SE of Holland City Limits NW'ly 2700-ft	Rieth-Riley Const. Co., Inc.	39-1	03-76	NB SB	0.40 0.41	0.54 0.54	0.47 0.48
Mb 11021-012 (01714A)	US 12 from 1.75 miles E of Galien E'ly 8.35 miles to W of US 12 BR	John Yerington Co.	41-38	14-36	EB WB	0.54 0.50	0.60 0.57	0.57 0.54
Mb 13031-018	M 66 from 100-ft S of "L" Drive N'ly to 350-ft N of "E" Drive	Rieth-Riley Const. Co., Inc.	39-1	13-38	NB SB	0.46 0.49	0.47 0.52	0.46 0.50
Mb 13071-011	Kalamazoo Ave (old US 27) from 0.5 mile S of Hughes Rd N'ly to US 27 BR - I 94 BL (Michigan Ave)	Rieth-Riley Const. Co., Inc.	39-1	13-38	NB SB	0.42 0.52	0.43 0.54	0.42 0.52
Mb 13072-005	US 27 BR (Kalamazoo Ave & Brewer St) from US 27 BR - I 94 BL (Michigan Ave) N'ly to I 94 interchange	Rieth-Riley Const. Co., Inc.	39-1	13-38	NB SB	0.48 0.49	0.52 0.51	0.50 0.50

1970 CONT.

TABLE 2 (Cont.)

BITUMINOUS CONCRETE (4.12) CONSTRUCTED IN 1969 and 1970

Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
Mb 14041 (01707A)	US 12 from E Village Limits of Edwardsburg E'ly 6.88 miles to 275-ft W of M 205 intersection	Rieth-Riley Const. Co., Inc.	39-1	14-36	EB	0.36	0.47	0.42
					WB	0.42	0.47	0.44
Mb 19031-008	US 27 from 1350-ft S of Herbison Rd N'ly to 3125-ft N of Round Lake Rd	Spartan Asphalt Paving Co.	47-3	47-43	NBOL	0.49	0.50	0.50
					NBIL	0.57	0.58	0.58
					SBOL	0.48	0.50	0.49
					SBIL	0.54	0.57	0.55
I 20052-001 (1)	I 75 from Roscommon-Crawford Co. Line (M 18 - M 76) N'ly to 4 Mile Rd	Lake & Howell Const. Co.	72-5	72-5	NBOL	0.58	0.62	0.60
					NBIL	0.56	0.60	0.58
					SBOL	0.58	0.62	0.60
					SBIL	0.58	0.64	0.61
Mb 23052-002 (part) (2) (00290A)	M 50 from M 43 SE to M 78 in Charlotte	Spartan Asphalt Paving Co.	41-38	34-49	NWB	0.28	0.56	0.45
					SEB	0.22	0.52	0.43
Mb 23052-002 (part) (2) (00290A)	M 50 from Flanders Rd, E of Charlotte, SE'ly to M 99 in Eaton Rapids	Spartan Asphalt Paving Co.	41-38	34-49	NWB	0.44	0.52	0.48
					SEB	0.45	0.48	0.46
Mb 33042-011 (part)	EB M 43 (Saginaw St) from W of Logan St E'ly to E of Capitol Ave, City of Lansing	Rieth-Riley Const. Co., Inc.	47-3	23-92	EBOL	0.49	0.51	0.50
					EB#3	0.50	0.53	0.51
					EB#2	0.51	0.51	0.51
					EBIL	0.47	0.51	0.49
Mb 33042-011 (part)	EB M 43 - M 78 BR from Pennsylvania Ave E'ly to WB M 43 - M 78 BR (Grand River Ave), City of Lansing	Rieth-Riley Const. Co., Inc.	47-3	23-92	EBOL	0.42	0.46	0.44
					EB#3	0.40	0.44	0.42
					EB#2	0.44	0.45	0.44
					EBIL	0.41	0.45	0.43
SS 39081-010	M 43 from 0.2 mile W of US 131 E'ly to Sage St in Kalamazoo	Rieth-Riley Const. Co., Inc.	39-1	39-1	EBOL	0.49	0.50	0.50
					EBIL	0.48	0.52	0.50
					WBOL	0.42	0.44	0.43
					WBIL	0.47	0.48	0.47
Mb 41031-005 (part) (00576A)	M 37 from Kraft Rd NW'ly to 1000-ft S of M 11 (28th St)	Woodland Paving Co.	41-38	41-27	NB	0.54	0.58	0.56
					SB	0.47	0.50	0.48

(1) Leveling course only - no wearing course contracted for

(2) For additional test data see Bituminous Aggregate Surfaces and 1970 Special Requests 7, 8, and 13.

TABLE 2 (Cont.)
BITUMINOUS CONCRETE (4.12) CONSTRUCTED IN 1969 and 1970

1970 CONT.

Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
Mb 41031-005 (part) (00675A)	M 44 from 1700-ft S of Burton St N'ly to 514-ft S of Lake Drive	Woodland Paving Co.	41-38	41-27	NB SB	0.55 0.50	0.57 0.52	0.56 0.51
Mb 41031-005 (part) (00675A)	M 45 from W City Limits of Grand Rapids E'ly to Bridge St	Woodland Paving Co.	41-38	41-27	EBOL EBIL WBOL WBIL	0.50 0.56 0.52 0.58	0.54 0.58 0.55 0.61	0.52 0.57 0.53 0.59
SS 41101-002	M 44 (Belding Rd) from Ramsdell Dr E'ly to 217-ft E of Lincoln Lake Ave	Rieth-Riley Const. Co., Inc.	41-69	41-113	EB WB	0.49 0.52	0.52 0.53	0.51 0.52
U 44011-003	M 24 (Lapeer Rd) from Turrill Rd N'ly to N of Pearl St	Cooke Contracting Co.	50-35	50-35	NBOL NBIL SBOL SBIL	0.48 0.55 0.42 0.52	0.49 0.60 0.46 0.54	0.49 0.58 0.44 0.53
Mtb 44041-004	M 21 (Genesee St) from Millville Rd (W City Limits of Lapeer) E'ly to M 24 (Main St)	Ajax Asphalt Paving, Inc.	63-4	63-4	EBOL EBIL WBOL WBIL	0.46 0.48 0.44 0.46	0.48 0.54 0.48 0.50	0.47 0.51 0.45 0.47
Mb 44042-003	M 21 from 110-ft E of Dorrow Rd E'ly to 220-ft E of Cade Rd	Molesworth Contracting Co.	63-4	74-51	EB WB	0.48 0.43	0.49 0.49	0.49 0.45
Mb 44042-004	M 21 at E City Limits of Lapeer E'ly to Dorrow Rd	Williams Bro's Asphalt Paving Co.	63-4	63-4	EB WB	0.55 0.54	0.62 0.60	0.58 0.57
Mb 50051-033	US 25 (Gratiot Ave) from 14 Mile Rd NE'ly to Sunnyview St	Detroit Asphalt Paving Co.	47-3	50-41	SBOL SB#3 SB#2 SBIL	0.43 0.44 0.45 0.50	0.43 0.48 0.48 0.51	0.43 0.46 0.47 0.50
Mb 56021-005	M 20 from 61-ft W of Isabella-Midland Co. Line E'ly to 76-ft E of Castor Rd	The Hicks Co.	37-26	37-26	EB WB	0.44 0.44	0.46 0.48	0.46 0.45
Mb 58053-003[1]	US 24 from 50-ft S of Stoney Creek Bridge in Monroe Co. NE'ly to Carter Rd in Wayne Co. omitting at Huron River Bridge, in Flatrock and at West Rd intersection	Ayling-Cunningham Asphalt Paving Co. & Detroit Asphalt Paving Co.	E. C. Levy (Dix) & 47-3	E. C. Levy (Dix) & 47-3	NBOL NBIL SBOL SBIL	0.54 0.58 0.53 0.55	0.59 0.62 0.56 0.60	0.56 0.60 0.54 0.57
F 61012-002	M 120 from Village Limits of Holton NE'ly to M 82 Junction	Paul C. Miller	70-9	70-9	NB SB	0.42 0.41	0.46 0.43	0.44 0.42

(1) For additional test data see 1970 Special Request 14.

TABLE 2 (Cont.)

BITUMINOUS CONCRETE (4.12) CONSTRUCTED IN 1969 and 1970

1970 CONT.

Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
Mb 63051-033	SB US 10 (Woodward Ave) from Webster Rd (Royal Oak-Berkley City Limits) SE'ly to Fielding Ave, omitting from Harrison St to Oakland Park Blvd	A. & A. Asphalt Paving Co., Inc.	63-4	63-4	SBOL	0.47	0.52	0.49
					SB#3	0.51	0.53	0.52
					SB#2	0.49	0.52	0.51
					SBIL	0.57	0.58	0.58
Mb 67051-002 (01613A)	M 115 from 1.51 miles NW of M 61 SE'ly to M 66	Hodgkiss & Douma, Inc.	67-2	67-2	EB	0.38	0.40	0.39
					WB	0.39	0.41	0.40
Mb 73051-003 (part) (01004A)	M 13 from 150-ft S of East St - Washington St intersection thence N'ly to 5th Ave, City of Saginaw	Saginaw Asphalt Paving Co.	47-3	63-54	NBOL	0.48	0.51	0.49
					NBIL	0.51	0.53	0.52
					SBOL	0.48	0.49	0.48
					SBIL	0.49	0.51	0.50
Mb 73051-003 (part) (01004A)	M 13 from 538-ft N of WB M 81 N'ly to N City Limits of Saginaw	Saginaw Asphalt Paving Co.	47-3	63-54	NBOL	0.48	0.51	0.49
					NBIL	0.51	0.54	0.53
					SBOL	0.46	0.47	0.47
					SBIL	0.45	0.50	0.48
Mb 73051-003 (part) (01004A)	M 81 from 28th St E'ly to 261-ft E of Outer Drive	Saginaw Asphalt Paving Co.	47-3	63-54	EB	0.42	0.46	0.44
					WB	0.44	0.45	0.44
Mb 77021-001	M 21 from E of Lapeer-St. Clair Co. Line E'ly to E of Sheridan Rd, omitting from 130-ft W of M 21 - Imlay City Drive to 190-ft E of Conners Rd	Molesworth Contracting Co.	50-35	74-51	EB	0.52	0.58	0.56
					WB	0.54	0.57	0.55
U 82081-023	M 153 (Ford Rd) from 299-ft E of Appoline St E'ly to Wyoming, Cities of Detroit & Dearborn	Ajax Asphalt Paving, Inc.	E. C. Levy (Dix)	E. C. Levy (Dix)	EBOL	0.49	0.55	0.52
					EBCL	0.51	0.58	0.55
					EBIL	0.59	0.60	0.59
					WBOL	0.62	0.66	0.64
					WBCL	0.59	0.61	0.60
					WBIL	0.61	0.62	0.62
Mtb 82144-018	M 29 from Sunningdale Ave E'ly to E Limits of Grosse Pointe Woods	Detroit Asphalt Paving Co.	47-3 & 50-41	47-15 & 50-41	EBOL	0.50	0.52	0.51
					EBIL	0.50	0.55	0.53
					WBOL	0.48	0.48	0.48
					WBIL	0.46	0.51	0.49
Mb 82211-027	M 85 (Fort St) from 150-ft S of LeRoy St in Trenton, N'ly to Peters St, City of Detroit	Asphalt Products Corp.	E. C. Levy (Dix)	E. C. Levy (Dix)	NBOL	0.43	0.56	0.51
					NBCL	0.57	0.58	0.58
					NBIL	0.51	0.60	0.55
					SBOL	0.41	0.56	0.48
					SBCL	0.54	0.55	0.54
					SBIL	0.48	0.62	0.55

TABLE 3

BITUMINOUS AGGREGATE (4.11) CONSTRUCTED IN 1969 and 1970

Year	Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources Coarse	Aggregate Sources Fine	Direction and Lane	Coefficient of Wet Sliding Friction Low	High	Avg
1969	Mtb 06011-003	M 76 from Wheeler Rd NW'ly to 250-ft S of Maple Ridge Rd	Central Paving Co.	65-46	----	EB WB	0.40 0.36	0.52 0.54	0.47 0.46
	Mb 41071-001	M 50 (Alden Nash Rd) from 84th St N'ly to 1770-ft S of I 96	Rieth-Riley Const. Co., Inc.	41-46	----	NB SB	0.56 0.58	0.58 0.61	0.57 0.60
	Mtb 41122-009	Old M 57 (14 Mile Rd) from US 131 E'ly 0.89 mile	Rieth-Riley Const. Co., Inc.	41-101	----	EB WB	0.66 0.64	0.70 0.64	0.68 0.64
	SS 45041-003	M 204 from M 22 E'ly to County Rd 641	Peninsula Asphalt Corp.	45-19	----	EB WB	0.41 0.40	0.44 0.42	0.42 0.42
	Mb 65052-005	M 33 from 210-ft N of M 55 N'ly to 503-ft N of S City Limits of Rose City	Central Paving Co.	65-46 & 65-52	----	NB SB	0.56 0.58	0.58 0.62	0.57 0.61
	Mb 68011-004	M 33 from 1894-ft S of Ogemaw-Oscoda Co. Line, N'ly 10 miles to Mio	Central Paving Co.	65-52	----	NB SB	0.64 0.62	0.67 0.64	0.65 0.63
1970	Mb 11074-004	M 140 from US 31 - US 33 N'ly to M 62	Rieth-Riley Const. Co., Inc.	14-55	----	NB SB	0.45 0.45	0.50 0.52	0.46 0.49
	Mb 16023-003	M 27 in Village of Topinabee	Lake & Howell Const. Co.	16-69	----	NB SB	0.36 0.32	0.46 0.47	0.40 0.40
	Mtb 20051-002 [1]	M 18 - M 76 from US 27 - Proposed I 75 E'ly to Proposed I 75 at Crawford-Roscommon Line	Lake & Howell Const. Co.	20-33	----	NB SB	0.35 0.39	0.45 0.50	0.41 0.44
	Mb 23052-002 [2] (part) (00290A)	M 50 at Fawn Lane Rd (1st patch W of US 127)	Spartan Asphalt Paving Co.	23-91	----	NWB SEB	0.20 0.16	0.24 0.29	0.22 0.22
	Mb 23052-002 [2] (part) (00290A)	M 50 at Blackman Rd (2nd patch W of US 127)	Spartan Asphalt Paving Co.	23-91	----	NWB SEB	0.22 0.27	0.28 0.31	0.25 0.29
	Mb 23052-002 [2] (part) (00290A)	M 50 at Woodard Rd (3rd patch W of US 127)	Spartan Asphalt Paving Co.	23-91	----	NWB SEB	0.40 0.34	0.44 0.39	0.43 0.37
	Mb 23052-002 [2] (part) (00290A)	M 50 through Thompkins Center (4th patch W of US 127)	Spartan Asphalt Paving Co.	23-91	----	NWB SEB	0.18 0.29	0.38 0.40	0.30 0.35
	Mb 32092-010 (01565A)	US 25 from Lytle St, in Village of Harbor Beach, N'ly to Main St in Village of Port Hope	Rieth-Riley Const. Co., Inc.	32-48	----	NB SB	0.47 0.48	0.51 0.51	0.49 0.49

(1) For additional test data see 1970 Special Request 5

(2) For additional test data see Bituminous Concrete Surfaces and 1970 Special Requests 7, 8, and 13.

TABLE 3 (Cont.)

BITUMINOUS AGGREGATE (4.11) CONSTRUCTED IN 1969 and 1970

1970 CONT.

Project No. and/or Job No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
			Coarse	Fine		Low	High	Avg
Mb 48032-005	M 123 from S Village Limits of Newberry N to Helen St	George Hocking Const. Co.	48-6	----	NB SB	0.37 0.36	0.39 0.37	0.38 0.37
Mb 62014-006	Proposed M 20 (One Mile Rd) from Croswell Ave E'ly to Tulip St	Rieth-Riley Const. Co., Inc.	62-34	----	EB WB	0.40 0.38	0.46 0.45	0.43 0.40
Mb 62021-002	M 82 from 647-ft N of M 120 (Muskegon-Oceana Co. Line) N'ly to 360-ft S of Church St, in Hesperia	Paul C. Miller	64-41 & 64-46	----	NB SB	0.36 0.31	0.40 0.36	0.37 0.33
Mb 66051-001 (part)[1]	M 26 from US 45, in Ontonagon Co., NE'ly to 160-ft E of Copper Range RR Crossing in Houghton Co.	George Hocking Const. Co.	66-77 & 66-78	Isle Royal Stamp Sand	NB SB	0.42 0.51	0.55 0.54	0.48 0.52
Mb 66051-001 (part)[1]	M 28 from 1.2 miles W of Kenton E'ly intermittently 5.4 miles	George Hocking Const. Co.	66-78	Isle Royal Stamp Sand	EB WB	0.48 0.51	0.52 0.51	0.50 0.51
Mb 72093-002	M 18 - M 76 from Proposed I 75 at Crawford-Roscommon Co. Line E'ly to E of Billman Rd	Lake & Howell Const. Co.	20-33	----	NB SB	0.34 0.38	0.47 0.49	0.42 0.45
Mb 74062-002	M 46 from E Limits of Carsonville E'ly to 280-ft W of US 25 omitting from W Limits to Church St in Port Sanilac	Frank Strausberg & Son, Co.	74-10	----	EB WB	0.60 0.49	0.61 0.51	0.60 0.50
Mb 77041-002	M 136 from 325-ft E of M 19 E'ly to 950-ft E of Black River Bridge	Blue Water Asphalt Co., Inc.	17-40	74-4	EB WB	0.54 0.53	0.56 0.58	0.55 0.56
Mb 80071-005 (part)[2]	M 43 from 0.7 mile W of M 40 W'ly, intermittently 5.7 miles	John Yerington Co.	80-20	----	EB WB	0.24 0.16	0.38 0.37	0.32 0.26
Mb 80071-005 (part)[2]	M 40, five patches SW of Decatur	John Yerington Co.	80-20	----	NB SB	0.16 0.17	0.39 0.42	0.25 0.31
Mb 80071-005 (part)[2]	M 119 from M 216 S the entire length of the curb and gutter section in Marcellus	John Yerington Con.	80-20	----	NB SB	0.45 0.48	0.53 0.53	0.49 0.50
Mm OBA-1A	M 28 from Soo Line RR Crossing, 0.3 mi. SW of Tula in Gogebic Co. E'ly to Merriweather Creek Bridge, 300-ft E of M 64 in Ontonagon Co.	Mathy Construction Co.	66-63	----	EB WB	0.52 0.54	0.58 0.59	0.54 0.56

(1) For additional test data see Miscellaneous Bituminous Surfaces.

(2) For additional test data see 1970 Special Requests 4 and 6.

TABLE 4
MISCELLANEOUS BITUMINOUS SURFACES CONSTRUCTED IN 1969 and 1970

	Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Coefficient of Wet Sliding Friction		
				Coarse	Fine		Low	High	Avg
1969	NON-SKID SURFACE TREATMENT								
1969	Mm OSC-7A	M 89 from 27th St E'ly to M 43	Rieth-Riley Const. Co., Inc.	03-34	----	EB WB	0.53 0.53	0.59 0.56	0.56 0.55
1969	STONE-FILLED SAND-ASPHALT AND SIMILAR SURFACES								
1969	Mb 38071-010	M 50 from 2400-ft E of Hand Rd in Lenawee Co., W'ly & N'ly to Stoney Lake Rd, in Jackson Co., omitting at US 12 and at divided roadway in Village of Brooklyn	Rieth-Riley Const. Co., Inc.	47-3	42-28	NB SB	0.62 0.65	0.65 0.69	0.64 0.67
1969	Ms 63052-021	US 10 (Southbound outside lane only) from 2361-ft NW of, to 784-ft SE of Bataan Rd	Lake & Howell Const. Co.	47-3	47-26	SBOL	0.50	0.55	0.53
1969	Ms 82053-045 (part)[1]	US 24 (Telegraph Rd) at Joy Rd	Asphalt Products, Corp.	E. C. Levy (Dix)	E. C. Levy (Dix)	NBOL NB#3 NB#2 NBIL	0.52 0.45 0.40 0.47	0.57 0.47 0.45 0.49	0.54 0.46 0.42 0.48
1969	Ms 82053-045 (part)[1]	US 24 (Telegraph Rd) at Warren Rd	Asphalt Products, Corp.	----	E. C. Levy (Dix)	NBOL NB#3 NB#2 NBIL SBOL SBCL SBIL	0.33 0.30 0.31 0.37 0.28 0.34 0.37	0.39 0.31 0.33 0.41 0.32 0.37 0.43	0.36 0.30 0.32 0.39 0.30 0.35 0.40
1970	Mb 21021-003	US 2 - US 41 from end of curb & gutter section in Escanaba W'ly to Delta-Menominee County Line	Payne & Dolan of Wisc., Inc.	21-53	21-45	EB WB	0.52 0.52	0.57 0.56	0.55 0.54
1970	Mb 21024-011	US 2 from Big Fishdam River, in Delta Co., E'ly to M 149 in Schoolcraft Co.	Mathy Construction Co.	75-5	70-9	EB WB	0.40 0.42	0.48 0.46	0.44 0.44
1970	Mb 66051-001 (part)[2]	M 26 from US 45, in Ontonagon Co., NE'ly to 160-ft E of Copper Range RR Crossing in Houghton Co.	Hocking Const. Co.	66-78	Isle Royal Stamp Sand	NB SB	0.62 0.60	0.64 0.64	0.63 0.62
1970	Ms 77032-008	US 25 from Court St NE'ly to Glenwood Ave, City of Port Huron	Blue Water Asphalt Co., Inc.	17-40	74-4	NBOL NBIL SBOL SBIL	0.45 0.51 0.47 0.51	0.47 0.53 0.49 0.53	0.46 0.52 0.47 0.52
1970	Mb 80071-005 (part)[3]	M 40, S from 40th Ave, 2.2 miles N of Paw-Paw	John Yerington Co.	41-38	80-20	NB SB	0.53 0.51	0.56 0.55	0.54 0.53

(1) For additional test data see 1970 Special Request 3.

(2) For additional test data see Bituminous Aggregate Surfaces.

(3) For additional test data see 1970 Special Requests 4 and 6.

TABLE 5
CONVENTIONAL CONCRETE AND BITUMINOUS
PAVEMENT SUMMARY

Surface Type	Service Year When Tested	Total Lanes Tested	Total Lane Miles Tested	Average Friction Level
Concrete	Initial	24	79.838	0.50
Concrete	1	71	113.124	0.43
Bituminous Concrete	Initial	106	442.302	0.44
Bituminous Concrete	1	46	122.354	0.47
Bituminous Aggregate	Initial	40	168.642	0.42
Bituminous Aggregate	1	12	72.700	0.53
NSST	1	2	5.600	0.56
Stone-filled Sand-asphalt	Initial	12	86.002	0.52
Stone-filled Sand-asphalt	1	14	22.163	0.48

SECTION II

FRICTION LEVELS DETERMINED FOR PAVEMENTS AFTER FIVE YEARS OF SERVICE

FRICTION LEVELS DETERMINED FOR PAVEMENTS AFTER FIVE YEARS OF SERVICE

Tables 6 through 9 contain skid test results from 35 portland cement concrete projects consisting of 94 lanes (220.576 lane miles) which were constructed during 1965. Initial-year skid tests were conducted on 13 of these projects and resulting wsf values averaged 0.53. Nine of these projects, tested in 1966 after one year's service, had an average coefficient of 0.47. Twelve projects were first tested during their second service year (1967) and, at that time, had an average friction level of 0.45. The remaining 1965 construction project was not tested until 1968, the third year of service, and it had an average coefficient of 0.49. After five years of service, these same 35 projects were retested and 19 of the 94 lanes, representing 18.8 percent of the total lane mileage, showed average coefficients below the Departmental Safety Standard. Projects U 30032A, C1; F 50022A, C5; U 13121G, C6; U 73073B, C9; and U 70012B, C2 had average five-year values below 0.40 on all lanes tested.

Tables 10 through 12 list skid test results of 37 bituminous concrete projects constructed during 1965. In all, 95 lanes (419.579 lane miles) were tested. Average coefficients of wsf determined in the initial and after the first and second service years averaged 0.48, 0.44, and 0.35, respectively. Eight of the 37 lanes produced average five-year friction levels below 0.40. These eight lanes represent 8.0 percent of the total lane mileage tested.

Four of the bituminous aggregate projects, shown in Tables 13 and 14, were skid-tested during their initial service year and 9 were tested after a one-year service period. Average wsf values were 0.48 and 0.43, respectively. Excellent friction levels were determined on these projects after a five-year service period. Average coefficients on all 158.152 lane miles tested were above the 0.40 mark, ranging from 0.49 to 0.73.

Seven non-skid surface treatments constructed during 1965 and shown in Table 15 were first tested after a one-year service period. At this time, although the average NSST friction level was 0.45, five of the 20 lanes (31.6 percent of the total lane mileage) exhibited friction levels below 0.40. Skid tests conducted after the fifth service year averaged 0.52. All five lanes which were below the Departmental Safety Standard at the one-year service level tested above 0.40 at the five-year level. However, average coefficients on the M 131 portion of Project Mm 6SC-4B, located between Middle Village Rd and a point north of Robinson Rd in Emmet County, decreased from 0.61 to 0.38 and from 0.59 to 0.38 on the north and southbound lanes, respectively.

Portland cement concrete, bituminous concrete, bituminous aggregate, and non-skid surface course pavements which were constructed in 1963, 1964, and 1965, and which had skid tests conducted at the one- and five-year service level, were selected for further study. Correlations determined between one- and five-year wsf values make it possible to estimate, within certain confidence limits, a five-year friction level from a one-year value. The following is a summary of determinations made from 395 lanes studied.

Portland Cement Concrete

One hundred thirty-one portland cement concrete lanes yielded an average one-year wsf value of 0.53. The average five-year coefficient was 0.51 or 0.02 lower.

Bituminous Concrete

The average one-year friction level determined on 200 lanes of bituminous concrete was 0.46. The average five-year value was 0.52, thereby indicating an increase of 0.06 in skid resistance after four additional years of service.

Bituminous Aggregate

At the one- and five-year service level, average coefficients of 0.50 and 0.58, respectively, were determined on 44 lanes of bituminous aggregate pavements.

Non-Skid Surface Treatments

To date, only 20 lanes of non-skid surface treatment projects have had one- and five-year skid tests conducted. Test results show an average increase of 0.07 after five years of service. The one- and five-year coefficients averaged 0.45 and 0.52, respectively.

Linear regressions relating one- and five-year wsf values were computed for concrete, bituminous concrete, bituminous aggregate, and non-skid surface treatment pavements which were constructed during 1963, 1964, or 1965. Graphs shown in Figure 1 have the following information for each surface type.

a) Equation of Best Fit Line— This line makes it possible to estimate within certain confidence levels, five-year wsf values from one-year wsf values.

b) Correlation Coefficient— The closer this figure is to 1, the better the linear relationship between variables being compared. The closer the number is to 0, the poorer the linear relationship.

c) Standard Error of Estimate— This is a measure of the confidence level of the linear relationship found between the one- and five-year wsf values and is expressed in terms of Y-scale units. The band formed by the standard error will contain about 68 percent of the data.

d) Sample Size— The number of lanes with average one-year wsf values and average five-year wsf values.

Trends noted in last year's report, "Summaries of Michigan Pavement Skid Resistance— 1969 Test Program," are continued with the addition of 1970 test data. Traffic tends to polish portland cement concrete surfaces and slightly reduce the skid resistance qualities after five years of service. Bituminous pavements have surface oils flushed away and, in general, show an increase in skid resistance at the five-year level. Extrapolating friction levels beyond the fifth service year, one might expect skid coefficients to level off and gradually decline as exposed aggregates become polished.

TABLE 6

CONCRETE PAVEMENTS TESTED DURING 1965 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1965	1970
I 11016A, C17	I 94 from US 31 - US 33 N to I 196	L. W. Lamb Co.	Pits 70-9 & 75-5	Pits 14-45, 14-55, & 80-20	EBIL	0.62	0.53
					WBIL	0.62	0.53
U 30032A, C1	M 99 from Spring St NW & N to S of Hillsdale	Titus Construction Co.	Pit 30-35	Pit 30-35	NBOL	0.47	0.32
					SBOL	0.47	0.31
USS 33011A, C5	M 99 from Eaton-Ingham Co. Line NE to I 96	Eisenhour Construction Co., Inc.	Pit 34-45	Pit 33-79	NBOL	0.52	0.42
					SBOL	0.56	0.46
I 39022C, C11	I 94 from Penn RR E to Sprinkle Rd	Carl Goodwin & Sons, Inc.	Pit 3-44	Pit 3-44	EBOL	0.48	0.40
					EBIL	0.55	0.46
					WBOL	0.42	0.40
					WBIL	0.50	0.51
I 39022C, C12	I 94 from S Westnedge Ave E to Lovers Lane	Carl Goodwin & Sons, Inc.	Pit 3-44	Pit 3-44	EBOL	0.40	0.39
					EBIL	0.42	0.44
					WBOL	0.43	0.46
					WBIL	0.56	0.47
F 50011F, C12	M 53 from 17 1/2 Mile Rd N to N of M 59, E of Utica	Sargent Construction Co.	Pit 63-4	Pit 63-4	NBOL	0.63	0.38
					NBIL	0.63	0.49
					SBOL	0.62	0.40
					SBIL	0.60	0.46
F 50013A, C1	M 53 from S of 21 Mile Rd N to S of 25 Mile Rd	Sargent Construction Co.	Pit 63-4	Pit 63-4	NBOL	0.58	0.39
					NBIL	0.61	0.52
					SBOL	0.65	0.36
					SBIL	0.64	0.50
F 50022A, C5	M 59 from existing M 53 in Utica E to M 53 relocation	Holloway Construction Co.	Pit 63-4	Pit 63-47	EBOL	0.50	0.31
					WBOL	0.49	0.32
Mb 58021A, C1	M 151 from E of US 23 E to US 25	L. W. Edison	Maumee Stone Co., Maumee, Ohio	Pit 46-16	EB	0.53	0.44
					WB	0.53	0.46
U 63043B, C2 U 63043F, C3 BI 63172A, C13	M 59 from GTW RR Grade Separation E to Mott Rd	L. W. Edison	Pit 63-4	Pit 63-4	EBOL	0.57	0.36
					EBIL	0.53	0.43
					WBOL	0.56	0.38
					WBIL	0.55	0.47
U 82061E, C7	US 12 EB (Michigan Ave) from Heywood St E to 4th St	L. A. Davidson	E. C. Levy (Dix Yd)	Pit 82-10	EBOL	0.50	0.42
					EB#3	0.51	0.43
					EB#2	0.52	0.44
					EBIL	0.55	0.46

TABLE 7
CONCRETE PAVEMENTS TESTED DURING 1966 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1966	1970
I 11015B, C36	I 94 from US 31 - US 33 S 4 mi. to bituminous concrete	Denton Construction Co.	Pits 70-9 & 75-5	Pits 14-58 & 80-20	NBIL	0.54	0.53
					SBIL	0.56	0.51
U 13121G, C6	I 94 from near Capital Ave E to "E" St in Battle Creek	Carl Goodwin & Sons, Inc.	Pit 8-80	Pit 8-80	NBOL	0.38	0.33
					NBIL	0.45	0.39
					SBOL	0.42	0.35
					SBIL	0.44	0.39
SS 22051A, C2	US 8 relocation from interstate bridge over Menominee River N to existing US 8	Bacco Construction Co.	Pit 22-4	Pit 22-4	NB	0.52	0.56
					SB	0.47	0.50
F 50013A, C2	M 53 relocation from N of 24 Mile Rd N to existing M 53	Sargent Construction Co.	Pit 63-4	Pit 63-4	NBOL	0.53	0.38
					NBIL	0.58	0.43
					SBOL	0.43	0.30
					SBIL	0.55	0.43
U 73073B, C9	M 81 (Davenport St) from Carolina St E to Schaefer St in Saginaw	W. F. McNally Co.	Pit 71-47	Pits 63-54 & 79-63	WBOL	0.36	0.28
					WBCL	0.36	0.31
					WBIL	0.40	0.30
SS 77052A, C3	M 29 relocation from 2550 ft S of Marysville N to 250 ft S of Bunce Ave on existing M 29	Anderson & Ruzzin, Inc.	Pit 75-5	Pit 74-51	NBOL	0.49	0.40
					NBIL	0.50	0.44
					SBOL	0.49	0.43
					SBIL	0.43	0.44
U 81104A, C18 U 81105A, C1 U 81105B, C2	M 14 relocation from 0.83 mi W of Wagner Rd NE to US 23 at the Huron River	Sargent Construction Co.	Pit 47-3	Pit 47-3	EBOL	0.46	0.48
					EBIL	0.46	0.60
					WBOL	0.46	0.47
					WBIL	0.47	0.59

TABLE 8
CONCRETE PAVEMENTS TESTED DURING 1967 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1967	1970
F 33035B, C1 BI 33084A, C21	US 127 relocation from S of Holt Rd to I 96	Sargent Construction Co.	Pit 33-79	Pit 47-3	NBOL	0.53	0.54
					NBIL	0.57	0.66
					SBOL	0.51	0.52
					SBIL	0.55	0.67
U 63031A, C15	US 24 from 1287 ft N of M 102 N'ly 2.717 mi., Oakland Co.	Cooke Contracting Co.			NBOL	0.41	0.38
					NB#3	0.45	0.41
					NB#2	0.37	0.47
					NBIL	0.39	0.42
					SBOL	0.38	0.35
					SB#3	0.41	0.40
					SB#2	0.43	0.45
					SBIL	0.42	0.42
U 70012B, C2	M 21 - US 31 BR from Fairbanks Ave E and NE to Clover St	Neil and Al Construction Co.	Pit 70-9	Pit 70-9	EBOL	0.38	0.32
					EBIL	0.42	0.35
					WBOL	0.45	0.35
					WBIL	0.45	0.35
BI 82191E, C17 I 82191F, C18	I 75 (Seaway Freeway) from N of Pennsylvania Rd NE to S of Allen Rd	Denton Construction Co.	Pit 63-4 & E. C. Levy	Pits 47-3, 63-4, 63-7, & 82-10	NBOL	0.43	0.40
					NBCL	0.47	0.45
					NBIL	0.49	0.52
					SBOL	0.41	0.41
					SBCL	0.48	0.46
					SBIL	0.48	0.49
I 82191G, C20 I 82191H. C21	I 75 (Seaway Freeway) from S of Allen Rd NE to S of Goddard Rd	Denton Construction Co.	Pit 63-64 & E. C. Levy	Pits 47-3, 63-4, 63-7, & 82-10	NBOL	0.42	0.39
					NBCL	0.46	0.44
					NBIL	0.46	0.48
					SBOL	0.41	0.41
					SBCL	0.47	0.44
					SBIL	0.47	0.47
I 82191J, C25 I 82191H, C26 I 82191I, C27 I 82191J, C28	I 75 (Seaway Freeway) from S of Goddard Rd NE to W of US 25 (Toledo Rd)	The Kutchins Co.	E. C. Levy (Trenton)	Pits 63-7, 63-55, & 82-10	NBOL	0.39	0.39
					NBCL	0.46	0.46
					NBIL	0.49	0.47
					SBOL	0.38	0.39
					SBCL	0.44	0.45
					SBIL	0.46	0.46

TABLE 9

CONCRETE PAVEMENTS TESTED DURING 1968 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1968	1970
U 77023D, C10	M 21 relocation (EB) from M 146 E'ly to US 25 (Military St) in Port Huron	Eisenhour Construction Co.	Pit 75-5	Pit 50-26	EBCL	0.50	0.38
					EBIL	0.47	0.40
					EBOL*	----	0.55

* parking lane

TABLE 10

BITUMINOUS CONCRETE PAVEMENTS (4.12) TESTED DURING 1965 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1965	1970
MB 13033C, C14	M 78 (Capitol Ave) from N of Columbia Ave N and NE, intermittently, to Jackson St	Rieth-Riley Construction Co., Inc.	Pit 39-1	Pit 13-38	NB SBOL SBIL	0.41 0.40 0.44	0.45 0.45 0.44
Mb 18031C, C4	US 27 BR from S of Schoolcrest Rd N and E to Wilcox Parkway	The Hicks Co.	Pit 37-26	Pit 37-26	SBOL	0.57	0.45
F 27023B, C3	US 2 from Gogebic Station SE 8.416 mi.	Mathy Construction Co.	Pit 27-66	Pit 27-66	EB WB	0.53 0.55	0.70 0.71
F 27023D, C4	US 2 from 8.416 mi. SE of Gogebic Station E to 1.250 mi. W of Watersmeet	Mathy Construction Co.	Pit 27-66	Pit 27-66	EB WB	0.54 0.52	0.70 0.70
F 28012A, C1 F 28051B, C2	M 37 from M 113 (Miller Rd) N to 4030 ft N of Silver Lake Shore Rd	Penninsula Asphalt & Construction Co.	Pit 45-19	Pit 45-19	NB SB	0.50 0.49	0.44 0.47
Mb 28021C, C2	M 113 from 1100 ft W of Knight & Townline Rd E to 1000 ft E of Knight & Townline Rd	Penninsula Asphalt & Construction Co.	Pit 45-19	Pit 45-19	EB WB	0.49 0.47	0.60 0.57
U 30032A, C1	M 99 from Spring St NW and N to S of N limits of Hillsdale	Ayling-Cunningham Asphalt Paving Co.	France Stone Waterfield, Ohio	Pit 30-35	NBIL SBIL	0.55 0.59	0.48 0.50
U 30041A, C2	M 34 from S of N limits of Hillsdale N to Bacon St	Ayling-Cunningham Asphalt Paving Co.	Pit 47-3	Pit 30-35	EBOL EBIL WBOL WBIL	0.58 0.55 0.55 0.57	0.48 0.48 0.47 0.47
USS 33011A, C5	M 99 from Eaton-Ingham Co. Line NE to I 96	Rieth-Riley Construction Co., Inc.	Pit 47-3	Pit 33-6	NBIL SBIL	0.59 0.60	0.56 0.62
F 34033A, C3 F 59051B, C3 F 59051A, C4	M 66 from M 44 N to Main St (Co. Rd. 522) in Stanton	Spartan Asphalt Paving Co.	Pit 34-53	Pits 34-26	NB SB	0.55 0.51	0.65 0.64

TABLE 10 (Cont.)
BITUMINOUS CONCRETE PAVEMENTS (4.12) TESTED DURING 1965 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1965	1970
U 37011C, C7	US 27 BL from Broomfield Rd N to 940 ft N of Preston Rd in Mt. Pleasant	The Hicks Co.	Pit 37-26	Pit 37-26	NBOL	0.48	0.49
					NBIL	0.44	0.43
					SBOL	0.42	0.37
					SBIL	0.41	0.42
F 50022A, C5	M 59 from existing M 53 in Utica E to M 53 relocation	Thompson-McCully Co.	Pit 63-4	Pit 50-35	EBIL	0.52	0.45
					WBIL	0.51	0.49
Mb 58021A, C1	M 151 from E of US 24 E to US 25	Ayling-Cunningham Asphalt Paving Co.	Pit 47-3	Pit 46-20	EB	0.46	0.51
					WB	0.49	0.53
BU 61153A, C1 BU 61153B, C2	US 31 BR from Spring St NE to proposed US 31 relocation	Reith-Riley Construction Co., Inc.	Pit 75-5	Pit 70-9	NBOL	0.41	0.38
					NB#3	0.43	0.40
					NB#2	0.37	0.38
					NBIL	0.47	0.47
					SBOL	0.47	0.44
					SB#3	0.46	0.37
					SB#2	0.53	0.37
					SBIL	0.58	0.49
SS 78054A, C2	M 78 from Wasepi Rd N to M 60	Reith-Riley Construction Co., Inc.	Pit 39-1 & Stone Street Pit, Brighton Indiana	Pit 12-35	NB	0.57	0.71
					SB	0.57	0.67
I 82022A, C24	I 94 WB (D.I.E.) from W of Beech-Daly Rd E to US 24	Thompson-McCully Co.	Pit 47-3	Pit 63-7	WBOL	0.44	0.47
					WBCL	0.44	0.49
					WBIL	0.47	0.51
Mb 82121C, C7	I 96 BR (Grand River Ave) from 6 Mile Rd (McNichols Rd) SE to Freeland Rd	Detroit Asphalt Paving Co.	Pit 47-3	Pit 47-3	NWBOL	0.44	0.42
					NWBIL	0.46	0.44
					SEBOL	0.41	0.43
					SEBIL	0.45	0.45
Mb 82131C, C9	US 10 (Woodward Ave) from E Grand Blvd NW to Clairmont St	Cooke Contracting Co.	Pit 63-4	Pit 63-4	NBOL	0.42	0.41
					NBIL	0.41	0.44
					SBOL	0.39	0.41
					SBIL	0.44	0.46

TABLE 11
BITUMINOUS CONCRETE PAVEMENTS (4.12) TESTED DURING 1966 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1966	1970
I 11014B, C9 I 11015A, C35	I 94 from LaPorte Rd NE to S limits of Bridgman	Rieth-Riley Construction Co., Inc.	US Steel Gary, Ind.	Pits 11-36 & 14-36	EBOL	0.40	0.42
					EBCL	0.50	0.63
					EBIL	0.56	0.70
					WBOL	0.39	0.48
					WBCL	0.52	0.61
					WBIL	0.64	0.72
I 11015B, C36	I 94 from concrete pavement, 4 mi. S of US 31 - US 33, S to Bridgman	Rieth-Riley Construction Co., Inc.	US Steel Gary, Ind.	Pit 11-36	EBOL	0.38	0.36
					EBCL	0.55	0.59
					EBIL	0.61	0.71
					WBOL	0.39	0.38
					WBCL	0.51	0.60
					WBIL	0.62	0.71
Mb 13121D, C12	I 94 BL (Dickman Rd) from GTW RR E to 20th St in Springfield	Rieth-Riley Construction Co., Inc.	Pit 13-30	Pit 13-30	EBOL	0.36	0.52
					EBIL	0.39	0.56
					WBOL	0.34	0.49
					WBIL	0.42	0.58
F 21024B, C4	US 2 from Sturgeon River E to Big Fishdam	Thornton Construction Co., Inc.	Pit 75-43	Local Pits	EB	0.50	0.61
					WB	0.51	0.54
F 24031A, C2 U 24031A, C3	US 131 from 1500 ft S of State Police Post, S of Petoskey, N to US 31 (Charlevoix St)	Hodgkiss & Douma, Inc.	Pit 17-20	Pit 15-32	NBOL	0.44	0.55
					NBIL	0.44	0.52
					SBOL	0.48	0.53
					SBIL	0.51	0.54
SS 29021A, C2	M 57 from Gratiot-Montcalm Co. Line E of Carson City, E to S limits of Perrington (Luce Rd)	The Hicks Co.	Pit 63-4	Pit 59-48	EB	0.46	0.64
					WB	0.49	0.66
U 44012C, C2	M 24 from Second St N to N limits of Lapeer	Flint Asphalt & Paving Co.	Pits 32-4 & 63-4	Pit 63-54	NBOL	0.38	0.53
					NBIL	0.38	0.56
					SBOL	0.42	0.52
					SBIL	0.39	0.53
SS 73031C C7 USS 76012A, C1 SS 76012B, C2	M 47 from M 21 in Owosso, N to 5th St in Oakley	Saginaw Asphalt Paving Co.	Pit 47-3	Local Pits	NBOL	0.44	0.54
					NBIL	0.41	0.51
					SBOL	0.46	0.56
					SBIL	0.41	0.50
U 78042A, C5	M 60 - US 131 BR from US 131 E to Rocky River in Three Rivers	Globe Construction Co.	Material Services Corp., Chicago, Ill.	Pit 78-25	EBOL	0.37	0.47
					EBIL	0.38	0.48
					WBOL	0.34	0.47
					WBIL	0.35	0.46
Mns 82041C, C11	M 17 from Monroe Blvd to Pelham Rd	Detroit Asphalt Paving Co.	Pit 47-3	Pit 47-3	EBOL	0.31	0.44
					EBIL	0.32	0.46
					WBOL	0.34	0.42
					WBIL	0.33	0.46

TABLE 12

BITUMINOUS CONCRETE PAVEMENTS (4.12) TESTED DURING 1967 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1967	1970
Mb 41062C, C7	M 11 from Clyde Park E to Division St., omitting from SB US 131 off-ramp to Buchanan Ave., City of Wyoming	Grand Rapids Asphalt Paving Co.	Pit 41-16	Pit 41-38	EBOL EBIL WBOL WBIL	0.33 0.34 0.35 0.37	0.39 0.41 0.41 0.45

TABLE 13

BITUMINOUS AGGREGATE PAVEMENTS (4.11) TESTED DURING 1965 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1965	1970
FFH 01023C, C4	M 72 from 11 mi. E of M 65 E to Co. Rd. #171	S. D. Solomon & Sons	Pit 01-57	None	EB WB	0.46 0.48	0.64 0.65
F 04021A, C4 F 04021B, C5 Mb 60022A, C2	M 32 from Hillman E to Bean Creek Rd	Lake & Howell Construction Co.	Pit 04-42	None	EB WB	0.45 0.51	0.54 0.57

TABLE 14
BITUMINOUS AGGREGATE PAVEMENTS (4.11) TESTED DURING 1966 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1966	1970
SS 05051A, C1	M 66 from US 131 N to Co. Rd. #620	Hodgkiss & Douma, Inc.	Pit 05-70	None	NB SB	0.48 0.49	0.49 0.49
F 16032C, C5	M 27 from N limits of Topinabee NE to NYCRR	Lake & Howell Construction Co.	Pit 16-64	None	NB SB	0.47 0.46	0.54 0.60
Mb 17043C, C3	M 48 from Co. Rd. intersection in Goetzville S to Caribou Lake Rd	Hodgkiss & Douma, Inc.	Pit 17-69	None	NB SB	0.48 0.47	0.73 0.72
F 32032C, C2	M 53 from 480 ft S of M 142 N to US 25 in Port Austin	Saginaw Asphalt Paving Co.	Pits 32-9, 32-10, 32-15 32-48, 32-51, 32-59, 32-60, & 74-10	None	NB SB	0.43 0.43	0.55 0.56
Mb 52032C, C7	M 35 from S limits of Palmer N 0.906 mi.	Payne & Dolan of Wisconsin, Inc.	Pit 52-9	None	NB SB	0.41 0.39	0.51 0.50
F 66021D, C5	M 28 - M 64 from Merriweather Creek NE to M 28 - M 64 junction W of Bergland	Mathy Construction Co.	Pit 66-63	None	NEB SWB	0.58 0.59	0.60 0.56
F 66022B, C3	M 28 from W of Ewen to 0.7 mi. E of Baltimore	Thornton Construction Co., Inc.	Pit 66-33	None	EB WB	0.34 0.33	0.58 0.53
F 66022A, C4	M 28 from M 64 (E Jct.) E to W branch of Ontonagon River	Thornton Construction Co., Inc.	Pits 27-27 & 66-63	None	EB WB	0.29 0.29	0.52 0.53
Mm 6BA-3B	US 31 N from 7 mi N of Scottville in Mason County	Laman Asphalt & Paving Co.	Pit 64-41	None	NB SB	0.42 0.40	0.50 0.50

TABLE 15
MISCELLANEOUS BITUMINOUS SURFACES TESTED DURING 1966 AND 1970

Project No.	Location	Paving Contractor	Aggregate Sources		Direction and Lane	Avg. Coefficient of Wet Sliding Friction	
			Coarse	Fine		1966	1970
Non-Skid Surface Treatments (4.06)							
Mm 5SC-5B	M 57 from Greenville E to M 66	Klett Construction Co.	Pit 34-51	None	EB WB	0.37 0.38	0.52 0.54
Mm 5SC-5C (part)	M 20 from E limits of White Cloud E to Newaygo-Mecosta Co. line	Rieth-Riley Construction Co., Inc.	Pit 54-27	None	NB SB	0.55 0.55	0.66 0.68
Mm 5SC-5C (part)	M 37 from N of White Cloud E to Newaygo-Lake Co. line	Rieth-Riley Construction Co., Inc.	Pit 54-27	None	NB SB	0.26 0.27	0.50 0.47
Mm 5SC-6B	M 18 from Gladwin-Roscommon Co. line S 17 mi.	Gilliland Construction and Equipment Co.	Pit 67-2	None	NB SB	0.45 0.48	0.48 0.46
Mm 5SC-6C	M 90 from Brown City E to M 19	Thompson-McCully Asphalt Paving Co.	Pit 50-35	None	EB WB	0.54 0.55	0.60 0.61
Mm 5SC-7A	M 37 from N limits of Middleville N to Barry-Kent Co. line	Bekman Co.	Pit 8-58	None	NB SB	0.46 0.43	0.63 0.61
Mm 6SC-4A	M 144 from W of AuSable River in Roscommon, E in Roscommon Co.	Comstock Construction Co.	Pit 71-15	None	EB WB	0.43 0.42	0.46 0.43
Mm 6SC-4B (part)	M 33 from 4 mi. N of M 68 N 5.8 mi.	Gilliland Construction and Equipment Co.	Pit 16-17	None	NB SB	0.47 0.45	0.48 0.55
Mm 6SC-4B (part)	M 33 from 12.3 mi. N of M 68 N 1.4 mi.	Gilliland Construction and Equipment Co.	Pit 16-17	None	NB SB	0.43 0.34	0.52 0.52
Mm 6SC-4B (part)	M 131 from 300 ft S of Middle Village Rd N to 1.5 mi. N of Robinson Rd	Gilliland Construction and Equipment Co.	Pit 16-17	None	NB SB	0.61 0.59	0.38 0.38
Sheet Asphalt (4.13)							
Mns 04031C, C2	US 23 at Werth Rd, 0.5 mi. SW of Alpena	Hodgkiss & Douma, Inc.	Pit 17-40	Pit 71-15	NB SB EB	0.38 0.39 0.37	0.65 0.58 0.62
Mm 6BC-7B	M 60 from M 66 (formerly M 78) NE to US 27, omitting Burlington	Rieth-Riley Construction Co., Inc.	None	Pit 12-35 & Local Pit	EB WB	0.52 0.54	0.63 0.64

TABLE 16
PORTLAND CEMENT CONCRETE PAVEMENTS CONSTRUCTED DURING 1965

Test Year	Number of Projects	Number of Lanes	Average WSF Value			Range of WSF Values	
			OL	IL	All Lanes	Low	High
1965	13	34	0.52	0.52	0.53	0.42	0.65
1966	9	23	0.45	0.49	0.47	0.36	0.58
1967	12	34	0.43	0.47	0.45	0.37	0.57
1968	1	2	----	----	0.49	0.47	0.50
1970(1)	13	34	0.38	0.48	0.42	0.31	0.53
1970(2)	9	23	0.38	0.46	0.43	0.28	0.60
1970(3)	12	34	0.40	0.48	0.44	0.32	0.67
1970(4)	1	3	----	----	0.44	0.38	0.55

(1) Initial tests conducted in 1965.
(2) Initial tests conducted in 1966.
(3) Initial tests conducted in 1967.
(4) Initial tests conducted in 1968.

TABLE 17
BITUMINOUS CONCRETE PAVEMENTS CONSTRUCTED DURING 1965

Test Year	Number of Projects	Number of Lanes	Average WSF Value			Range of WSF Values	
			OL	IL	All Lanes	Low	High
1965	22	51	0.46	0.50	0.48	0.37	0.60
1966	14	40	0.39	0.45	0.44	0.31	0.64
1967	1	4	0.34	0.36	0.35	0.33	0.37
1970(1)	22	51	0.44	0.48	0.50	0.37	0.71
1970(2)	14	40	0.48	0.56	0.54	0.36	0.72
1970(3)	1	4	0.40	0.43	0.42	0.39	0.45

(1) Initial tests conducted in 1965.
(2) Initial tests conducted in 1966.
(3) Initial tests conducted in 1967.

TABLE 18
BITUMINOUS AGGREGATE PAVEMENTS CONSTRUCTED
DURING 1965

Test Year	Number of Projects	Number of Lanes	Average WSF Value			Range of WSF Values	
			OL	IL	All Lanes	Low	High
1965	4	4	----	----	0.48	0.45	0.51
1966	9	18	----	----	0.43	0.29	0.59
1970[1]	4	4	----	----	0.60	0.54	0.65
1970[2]	9	18	----	----	0.56	0.49	0.73

(1) Initial tests conducted in 1965.
(2) Initial tests conducted in 1966.

TABLE 19
NON-SKID SURFACE TREATMENT PAVEMENTS CONSTRUCTED
DURING 1965

Test Year	Number of Projects	Number of Lanes	Average WSF Value			Range of WSF Values	
			OL	IL	All Lanes	Low	High
1966	7	20	----	----	0.45	0.26	0.61
1970[1]	7	20	----	----	0.52	0.38	0.68

(1) Initial tests conducted in 1966.

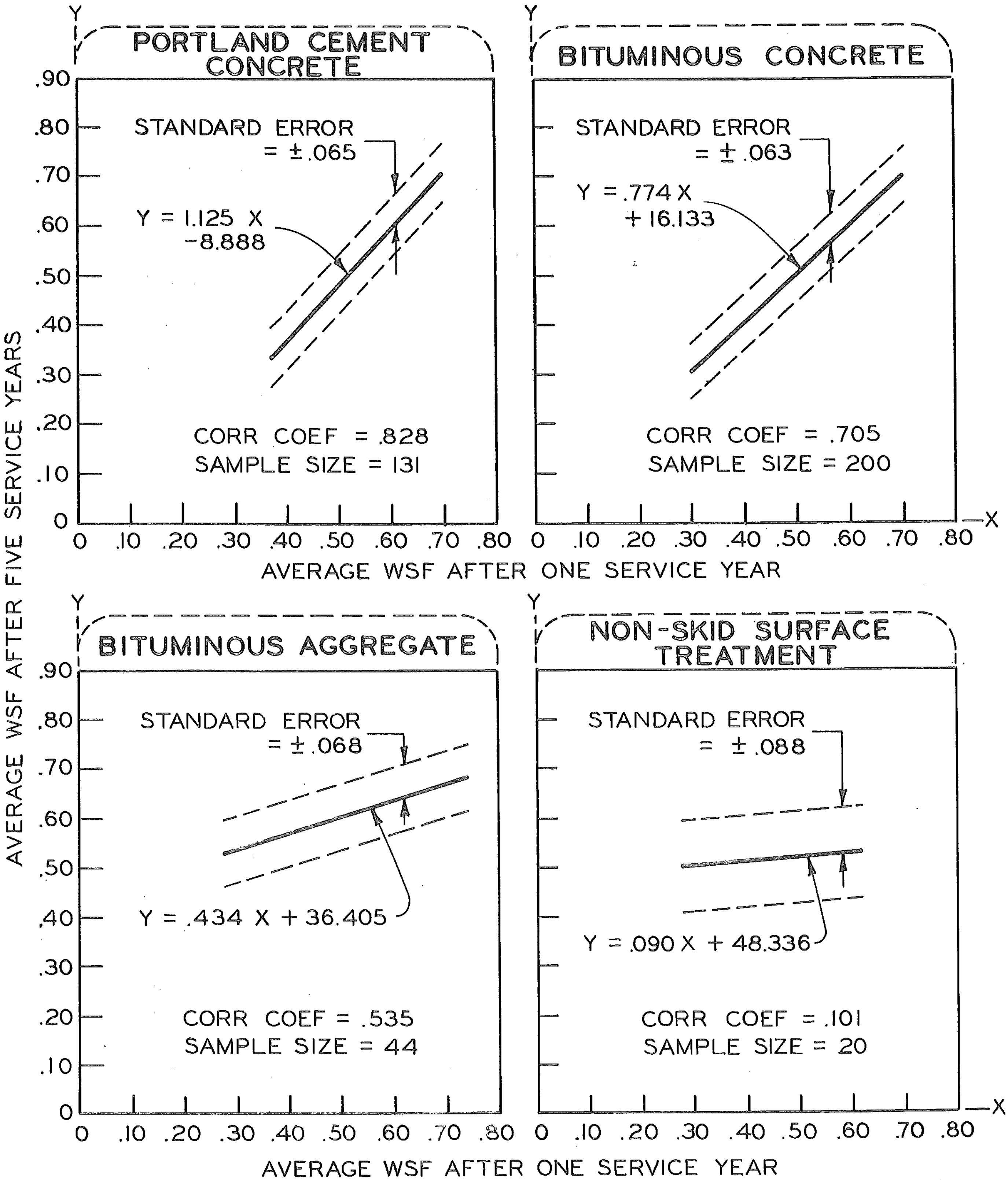


Figure 1. Relationship between one and five-year wet sliding friction values.

SECTION III

EXPERIMENTAL FEATURES IN PAVEMENT SURFACES

EXPERIMENTAL FEATURES IN PAVEMENT SURFACES

Table 20— Rubberized Sand-Asphalt; US 31, City of Charlevoix

Except for 1962, skid tests have been conducted annually on the rubberized sand-asphalt surface which was placed on US 31 in October of 1960. Table 20 summarizes these tests. The 1968 coefficients indicated an increased friction level over the 1967 values. During 1969, the friction level dropped 0.05 to a level identical to that determined initially in 1960. The 1970 friction level decreased insignificantly by 0.01 and this project continues to exhibit good skid resistance qualities.

Table 21— 3 BC Sand-Asphalt Resurfacing, US 131, North and South of Alba (Project Mm 4BC-3A, Control Section 05072)

Good skid resistance qualities have existed on this project since the 3 BC sand-asphalt surface was placed in 1964 and these qualities continued during the 1970 tests. Average wsf values, determined after six years of service, ranged from 0.57 to 0.60. Friction levels still do not indicate a significant difference in performance of the 85/100 penetration sand-asphalt using 6.9 percent bitumen and the 150/175 penetration sand-asphalt using 6.4 percent bitumen; both have performed well.

Table 22— Bituminous Concrete Interstate Projects

This table presents the results of skid tests taken on a representative sample of Interstate bituminous projects which were constructed during 1961 and 1962. The 1970 average wsf values range from 0.55 to 0.74 and average 0.65 for the inside (passing) lanes and from 0.41 to 0.66, averaging 0.56, for the outside (traffic) lanes. Previously established trends were continued this year as the inside lanes yield average friction levels 16.1 percent higher than the outside lanes with all values above the Departmental Safety Standard.

Table 23— Bridge Deck Surface Coatings

Table 23 summarizes skid tests for five types of bridge deck surface coatings placed on seventeen structures. Four structures (X01 of 11016, B01 of 45041, B01 of 35032, and B04 of 06073) tested and reported last year comparing types of coal-tar epoxy coatings have been deleted from this study.

1. Coal-Tar Epoxy Coatings

The single structure currently being tested under this surface type is B02 of 61151 carrying the northbound lanes of I 96BS and US 31BR over Black Creek. While initial test values in 1968 exhibited good skid resistance qualities, the surface condition and frictional properties on this project have deteriorated rapidly. After one year's service, average friction levels had dropped 41 percent to 0.34. The average friction level determined in 1970 of 0.22 is 62 percent lower than the initial values and 35 percent lower than last year's values.

2. Rubberized Bituminous Concrete

Five structures which were surfaced with rubberized bituminous concrete in 1967 were tested again in 1970 and yielded an average wsf value of 0.50. This figure is 3.8 percent lower than the average coefficient determined last year. Friction levels after the third service year have decreased on all but two of the 16 lanes tested. Friction level decreases ranged from 0.01 to 0.07 while the two lanes with increased skid resistance average a 0.025 rise in friction level.

Six structures surfaced in 1968 were skid tested again in 1970. Initially, friction levels ranged from 0.42 to 0.52 and averaged 0.45. After being subjected to weathering and traffic for two years, wsf values ranged from 0.34 to 0.50 and averaged 0.44. Average coefficients at the initial, one-, and two-year service level are similar, but by separating the structures into two categories based on traffic volume a difference is apparent. Structures in Category 1 bear an average daily traffic volume 20-percent lower than Category 2 structures. Category 1 (B01 of 61076, B02 of 61076, B03 of 61076, and S04 of 61072) yield average wsf values 6.7 percent higher at the two-year service level and Category 2 (S16 of 82111 and S17 of 82023) yield average wsf values 13.3 percent lower at the two-year service level.

3. Asbestos Mixtures

Two structures coated with bituminous mixtures containing asbestos were tested for the fourth consecutive year in 1970; both structures were coated in 1967. Bridge B05 of 58152 had a rubberized asbestos and bituminous concrete mixture applied to its deck. Wsf values obtained this year averaged 0.50, continuing to maintain good friction levels after the third service year. The northbound lanes of X01 of 81075 have been coated with a mix comprised of asbestos and sand asphalt, while the southbound has a mixture of rubberized bituminous concrete and sand-asphalt. Lanes in both directions have slightly decreased friction levels this year. Average wsf values determined in 1970 were 0.57 and 0.58, respectively, for the northbound and southbound lanes of X01 of 81075.

4. Polyurethane Coating

Bridge S18 of 82025 was coated with a special thin coating of polyurethane in 1968. Outside lanes averaged 0.49 after one year of service but inside lanes had dropped to a dangerously low average friction level of 0.18. Between the one- and two-year service levels, corrective treatment (maintenance repairs) has improved friction levels for this structure. Outside lanes as tested in 1970 average 0.53, 20 percent higher than 1969; inside lanes average 0.34, 88 percent higher than in 1969. Although the inside lane friction level of 0.34 is less than the Departmental Safety Standard, it is likely adequate for this location due to low traffic speeds necessitated by right-angle roadway alignment at the west end of the structure.

5. Epoxy Coatings

Skid tests were continued at the one-year service level on S05 of 23081. Friction levels for the north one-half, surfaced with E15-Versamid 140, average 0.54, 18.2 percent lower than initial levels. Friction levels for the south one-half, surfaced with Guardkote 250, average 0.50, 30.6 percent lower than initial levels. Following one year's service, although dropping considerably, friction levels remain adequate on both surfaces.

Added to this study in 1970 is the M 83 bridge over the Cass River, B02 of 73131, in Frankenmuth. This bridge was surfaced with epoxy mortar in August of 1969 and initial testing was conducted at the one-year service level in 1970. Average wsf values for 1970 range from 0.52 to 0.60 indicating good skid resistance qualities.

Table 24— Experimental Skid-Resistant Resurfacing

Skid tests were continued this year at 16 experimental skid-resistant resurfacing locations which were constructed in 1965. Five-year friction levels were below 0.40 on 12 percent of the 90 lanes tested in 1970. Fifty-two percent of the lanes exhibited average friction levels between 0.40 and 0.49, and 36 percent were 0.50 or higher.

For the fourth consecutive year, four of the experimental surface types exhibit outstanding friction levels with average wsf values on all lanes 0.50 or higher. Included in this outstanding performance category are:

1) 80-lb/sq yd sandstone plus asphalt: Control Sections 09033 and 09042.

2) 50-lb/sq yd quartzite plus asphalt: Control Sections 25072 and 25073.

3) 50-lb/sq yd 3BC sand plus hot asphalt emulsion: Control Section 81031.

4) 50-lb/sq yd 2MS sand plus hot asphalt emulsion: Control Section 81031.

Average wsf values for each of the other seven mixture types range from 0.40 to 0.50. Performing the poorest is the 50-lb 3BC plus asbestos fiber and asphalt experimental mixtures located in Control Sections 82052 and 82053. Here, eight of the 23 lanes tested have average five-year wsf values below the Departmental Safety Standard.

The 80-lb crushed fine aggregate mixture applied to the northbound lanes of US 24 in August of 1968 continued to show a decay in skid resistance for the second service year. Coefficients for all lanes of this surface type, however, averaged above 0.40.

Table 25— Textured Concrete Pavement Surfaces; Northbound I 69

Three special textured surface sites were constructed as part of Project I 13074-001 to investigate different methods of texturing concrete pavement surfaces and to evaluate their performance. These sites are located on the northbound lanes of I 69, north of I 94 between Stations 2241+50 and 2289+50 and were specially textured in three ways: 1) transverse finish using nylon brushes; 2) transverse finish using metal combs; and, 3) longitudinal finish using nylon brushes. Total length of these special textures was about 4,700 lineal ft of 24-ft roadway. The remainder of the project was finished with a conventional burlap drag. Table 25 summarizes various texturing methods, locations, and their initial skid resistance values.

TABLE 20
RUBBERIZED SAND-ASPHALT US 31, CITY OF CHARLEVOIX

Test Year	Average Coefficient of Wet Sliding Friction: Firestone Tire	Average Coefficient of Wet Sliding Friction: General Tire
1958*	0.19	----
1959**	0.48	----
1960	0.52	----
1961	0.40	----
1963	0.38	----
1964	----	0.46
1965	----	0.44
1966	----	0.40
1967	----	0.40
1968	----	0.57
1969	----	0.52
1970	----	0.51

* Initial tests on polished portland cement surface.

** Tests conducted on temporary seal coat applied in summer 1959, with surfacing in October 1960.

TABLE 21
3BC SAND-ASPHALT RESURFACING; US 131: NORTH AND SOUTH OF ALBA (PROJECT Mm 4BC-3A, CONTROL SECTION 05072)

Test Area Locations	Asphalt Cement	Aggregate	Mineral Filler	Direction and Lane	Average Coefficient of Wet Sliding Friction: July 1964	Oct. 1964	June 1965	Sept. 1966	Aug 1967	June 1968	July 1969	Oct. 1970
Mancelona to S of Alba	85/100 penetration (6.9-percent bitumen)	1:1 mixture from Polous and Gerstenberger Pits	fly ash (Detroit Edison)	SBOL/SB*	0.51	0.54	0.56	0.50	0.54	0.56	0.56	0.57
				SBIL/NB*	0.68	0.66	0.68	0.62	0.65	0.63	0.59	0.60
N of Alba to M32	150/175 penetration (6.4-percent bitumen)			SBOL/SB*	0.50	0.60	0.56	0.52	0.55	0.56	0.59	0.58
				SBIL/NB*	0.63	0.68	0.68	0.64	0.67	0.62	0.60	0.60

* Effective 11-12-68, US 131 has been returned to a two-lane roadway, with the elimination of the former NB lanes between M 66 and M 32. Consequently future traffic flow over the test area will carry north and southbound traffic.

TABLE 22

BITUMINOUS CONCRETE INTERSTATE PROJECTS

Project No.	Length, mi.	Location	Date Paved (Wearing Course)	Paving Contractor	Source of Coarse Aggregate	Lane[1]	Average Coefficient of Wet Sliding Friction										
							Firestone Tire				General Tire						
							1961	1962	Apr. 1963	Aug. 1963	1964	1965	1966	1967	1968	1969	1970
18034, C3	6.758	M 61 to Arnold Rd	May-June 1962	Rieth-Riley	Wallace Stone Co. (Pit 32-4)	IL	0.52[2]	----	----	----	0.58	0.64	0.56	0.59	0.60	0.65	0.57
						OL	0.51[2]	----	----	----	0.47	0.48	0.41	0.42	0.46	0.53	0.44
72014, C4 20016, C1	6.273	0.6 mi. S of Roscommon-Crawford Co. Line to M 18 - M 76	May-June 1962	Thornton Construction	Pickett, Schreur (Merrit Pit)	IL	----	0.51	----	0.58	0.68	0.63	0.56	0.64	0.64	0.72	0.72
						OL	----	0.48	----	0.53	0.59	0.53	0.49	0.54	0.59	0.66	0.63
20015, C3	4.847	Co. Rd 612 to N Crawford Co. Line	Sept. 1961	Thornton Construction	McCready Pit (Pit 60-18)	IL	0.60	0.60	0.61	0.59	0.73	0.66	0.59	0.66	0.65	0.73	0.70
						OL	0.56	0.52	0.56	0.51	0.63	0.59	0.52	0.54	0.60	0.70	0.66
69013, C1	7.665	Otsego Co. Line N	Oct. 1961	Saginaw Asphalt	Afton Quarry (Pit 20-35)	IL	----	----	0.57	0.59	0.70	0.60	0.49	0.58	0.52	0.58	0.55
						OL	----	----	0.49	0.54	0.54	0.44	0.36	0.40	0.41	0.48	0.41
		Marlette Rd to Charles Brink Rd	June 1962	Saginaw Asphalt	Afton Quarry (Pit 20-35)	IL	----	----	0.56	0.59	0.68	0.64	0.48	0.58	0.58	0.62	0.58
						OL	----	----	0.47	0.47	0.48	0.44	0.35	0.37	0.42	0.48	0.46
69013, C3, C5	5.385	Charles Brink Rd N to M 32 (Gaylord)	June 1962	Spartan Asphalt	Lewiston Pit	IL	----	----	0.59	0.63	0.71	0.66	0.60	0.70	0.66	0.73	0.72
						OL	----	----	0.54	0.57	0.62	0.57	0.50	0.56	0.58	0.67	0.66
16091, C9	2.629	0.5 mi. S of M 68 N to MC RR	Aug-Sept 1962	East Shore Asphalt	Big Cut Pit (Pit 71-15)	IL	----	0.62	----	0.63	0.75	0.75	0.70	0.70[3]	0.74	0.74	0.74
						OL	----	0.58	----	0.56	0.58	0.60	0.52	0.52[3]	0.58	0.62	0.63

(1) IL and OL denote passing and traffic lanes.
(2) Tested on leveling course mix.
(3) Average of 2 series of tests in 1967.

TABLE 23
BRIDGE DECK SURFACE COATINGS

Bridge No.	Location	Year Coated	Type of Coating	Direction and Lane	Average Coefficient of Wet Sliding Friction 1967	1968	1969	1970
B02 of61151	I 96 BS, US 31 BR over Black Creek	1968	Flexible coal tar epoxy & sand	NBOL	----	0.57	0.26	0.19
				NBIL	----	0.59	0.42	0.24
B01 of 09042	I 75 BL over Saginaw River in Bay City	1967	Rubberized bituminous concrete	EBOL	*	0.45	0.49	0.44
				EBIL	*	0.50	0.56	0.51
				WBOL	0.48	0.43	0.41	0.44
				WBIL	0.51	0.49	0.54	0.48
B02 of 11052	US 31 - US 33 over St. Joseph River in Berrien Springs	1967	Rubberized bituminous concrete	NB	*	0.39	0.47	0.40
				SB	0.43	0.36	0.43	0.37
X01 of 19032	US 27 over GTWRR in St. Johns	1967	Rubberized bituminous concrete	NBOL	0.53	0.44	0.50	0.47
				NBIL	0.56	0.50	0.55	0.52
				SBOL	0.53	0.48	0.51	0.49
				SBIL	0.60	0.56	0.57	0.56
X01 of 38101	I 94 over Grand River and NYCRR, Jackson	1967	Rubberized bituminous concrete	EBOL	0.52	0.49	0.55	0.51
				EBIL	0.59	0.55	0.63	0.61
				WBOL	0.54	0.43	0.51	0.50
				WBIL	0.55	0.53	0.56	0.58
B01 of 79051	M 24 over Cass River in Caro	1967	Rubberized bituminous concrete	NB	0.53	0.48	0.56	0.51
				SB	0.50	0.48	0.55	0.53
B01 of 61076	M 20 over Muskegon River	1968	Rubberized bituminous concrete	NBOL	----	0.46	0.49	0.49
				NBIL	----	0.48	0.53	0.50
				SBOL	----	0.44	0.49	0.46
				SBIL	----	0.44	0.52	0.49
B02 of 61076	M 20 SB over Cedar Creek	1968	Rubberized bituminous concrete	SBOL	----	0.44	0.50	0.48
				SBIL	----	0.44	0.55	0.60
B03 of 61076	M 20 NB over Cedar Creek	1968	Rubberized bituminous concrete	NBOL	----	0.46	0.52	0.49
				NBIL	----	0.45	0.54	0.53
S04 of 61072	M 46 over US 131	1968	Rubberized bituminous concrete	EBOL	----	0.45	0.45	0.43
				EBCL	----	0.43	0.49	0.49
				EBIL	----	0.45	0.54	0.50
				WBOL	----	0.42	0.48	0.43
				WBCL	----	0.43	0.49	0.47
				WBIL	----	0.50	0.55	0.50
S16 of 82111	Grand River Ave (I 96 BS) over I 696 BS	1968	Rubberized bituminous concrete	EBOL	----	0.52	0.47	0.46
				EBCL	----	0.44	0.43	0.40
				EBIL	----	0.43	0.41	0.41
				WBOL	----	0.49	0.49	0.47
				WBCL	----	0.42	0.39	0.40
				WBIL	----	0.43	0.41	0.41
S17 of 82023	Grand River Ave (I 96 BS) over I 94	1968	Rubberized bituminous concrete	EBOL	----	0.44	0.38	0.35
				EBCL	----	0.44	0.37	0.34
				EBIL	----	0.45	0.40	0.36
				WBOL	----	0.50	0.43	0.40
				WBCL	----	0.44	0.37	0.36
				WBIL	----	0.44	0.39	0.35
S05 of 58152	I 75 over Newport Rd, Newport	1967	Rubberized asbestos and bituminous concrete	EB	0.46	0.50	0.51	0.49
				WB	0.47	0.60	0.51	0.52
X01 of 81075	US 23 BR over Huron River, North of Ann Arbor	1967	Asbestos mix plus sand asphalt	NBOL	0.57	0.52	0.55	0.54
				NBCL	0.58	0.53	0.57	0.56
				NBIL	0.60	0.56	0.66	0.62
		1967	Rubberized bituminous concrete plus sand asphalt	SBOL	0.61	0.50	0.57	0.54
				SBCL	0.59	0.55	0.64	0.59
				SBIL	0.58	0.58	0.64	0.62
S18 of 62025	Allard Ave over I 94	1968	Special thin polyurethane coating	EBOL	----	0.46	0.42	0.52
				EBIL	----	0.40	0.16	0.34
				WBOL	----	0.55	0.45	0.54
				WBIL	----	0.44	0.20	0.35
S05 of 23081	Crietz Rd over I 496	1969	North half of deck only E 15 Versamid 140	NB	----	----	0.67	0.54**
				SB	----	----	0.66	0.54**
			South half of deck only Guard Kote 250	NB	----	----	0.75	0.52**
				SB	----	----	0.69	0.49**
B02 of 73131	M 83 over Cass River, Frankenmuth	Aug 1969	Epoxy Mortar	NBOL	----	----	----	0.67
				NBIL	----	----	----	0.52
				SBOL	----	----	----	0.60
				SBIL	----	----	----	0.56

* Not tested

**Average of spring and fall tests.

TABLE 24
EXPERIMENTAL SKID-RESISTANT RESURFACING

Control Section	Location	Construction Months	Mixture Type	Route	Direction and Lane	Average Coefficient of Wet Sliding Friction						
						1965	1966		1967	1968	1969	1970
							Spring	Fall				
09033	M 13 at Linwood Rd, N of Bay City	Oct. 1965	80-lb Sandstone + asphalt	M 13	NBOL	0.71	0.49	0.43	0.50	0.51	0.51	0.50
				M 13	NBIL	0.72	0.52	0.46	0.57	0.59	0.60	0.58
				M 13	SBOL	0.73	0.49	0.45	0.54	0.54	0.53	0.55
				M 13	SBIL	0.74	0.58	0.49	0.62	0.63	0.63	0.58
09033	M 13 at Grove St, N of Bay City	Sept.-Oct 1965	80-lb Sandstone + asphalt	M 13	NBOL	0.73	0.53	0.49	0.59	0.55	0.56	0.55
				M 13	NBIL	0.76	0.61	0.56	0.66	0.62	0.66	0.67
				M 13	SBOL	0.75	0.51	0.44	0.40	*	0.43[1]	0.52[1]
				M 13	SBIL	0.76	0.55	0.51	0.42	*	0.44[1]	0.55[1]
09042	M 25 at Wagner Rd, E of Bay City	Sept. 1965	80-lb Sandstone + asphalt	M 25	EB	0.77	0.53	0.47	0.51	0.54	0.64	0.62
				M 25	WB	0.74	0.54	0.47	0.53	0.55	0.66	0.60
25072	M 54 at Coldwater Rd, N of Flint	Oct. 1965	50-lb Quartzite + asphalt	M 54	NBOL	0.67	0.50	0.51	0.55	0.54	0.54	0.54
				M 54	NBIL	0.77	0.54	0.52	0.61	0.62	0.61	0.63
				M 54	SBOL	0.70	0.51	0.51	0.55	0.57	0.58	0.53
				M 54	SBIL	0.76	0.53	0.53	0.60	0.60	0.63	0.62
25073	M 54 at M 57, N of Flint	Sept. 1965	50-lb Quartzite + asphalt + additive	M 54BR	NBOL	0.70	0.48	0.43	0.53	0.56	0.61	0.53
				M 54BR	NBIL	0.71	0.53	0.47	0.55	0.58	0.61	0.59
				M 54BR	SBOL	0.65	0.50	0.44	0.52	0.55	[3]	0.54
				M 54BR	SBIL	0.71	0.52	0.49	0.58	0.61	[3]	0.61
				M 57	EB	0.70	0.51	0.45	0.55	0.56	0.55	[4]
				M 57	WB	0.72	0.53	0.48	0.55	0.56	0.57	[4]
25072	M 54 at M 54BR (S Jct.) S of Flint	Oct. 1965	50-lb crushed beach pebbles + asphalt	M 54	NBOL	0.60	0.49	0.43	0.42	0.43	0.48	0.42
				M 54	NBIL	0.66	0.47	0.41	0.44	0.45	0.52	0.49
				M 54BR	SBOL	0.62	0.47	0.46	0.40	0.44	0.48	0.38
				M 54BR	SBIL	0.66	0.47	0.41	0.41	0.48	0.54	0.48
				M 54 (Dort)	WBOL	0.62	0.45	0.45	0.46	0.50	0.54	0.52
				M 54 (Dort)	WBIL	0.62	0.45	0.47	0.48	0.52	0.55	0.50
81031	US 12, W from Neblo Rd, NW of Clinton	Sept. 1965	50-lb 3BC + hot asphalt emulsion	US 12	EB	0.60	0.49	0.49	0.49	0.52	0.51	0.52
				US 12	WB	0.62	0.47	0.45	0.49	0.55	0.52	0.50
81031	US 12, E from Lima Center Rd, NW of Clinton	Sept. 1965	50-lb 2MS + hot asphalt emulsion	US 12	EB	0.58	0.48	0.44	0.55	0.55	0.57	0.52
				US 12	WB	0.60	0.49	0.47	0.54	0.54	0.57	0.55
82052	US 24 at Fenkell Rd, (Five Mile Rd), Detroit	Sept. 1965	50-lb 3BC + asbestos fiber + asphalt	US 24	NBOL	0.56	0.36	0.34	0.37	0.38	0.42	0.35
				US 24	NB#3	0.53	0.36	0.34	0.41	0.40	0.41	0.38
				US 24	NB#2	0.57	0.36	0.34	0.40	0.41	0.43	0.41
				US 24	NBIL	0.60	*	*	*	*	*	*
				US 24	SBOL	0.52	0.38	0.37	0.41	0.39	0.43	0.38
				US 24	SBCL	0.60	0.37	0.35	0.42	0.42	0.43	0.40
				US 24	SBIL	0.59	0.35	0.34	0.44	0.40	0.42	0.40
				Five Mile Rd	EBOL	0.51	0.37	0.31	0.36	0.38	0.37	0.37
				Five Mile Rd	EBIL	0.55	0.39	0.33	0.41	0.40	0.42	0.41
				Five Mile Rd	WBOL	0.55	0.37	0.33	0.39	0.40	0.44	0.41
				Five Mile Rd	WBIL	0.60	0.39	0.33	0.43	0.44	0.44	0.42

* Not tested
(1) Bituminous Concrete - non-experimental
(2) NBOL IWT (entire pad) and stopping area worn to original surface
(3) Work being done at intersection -- SB too dirty to test
(4) Deleted by new construction

TABLE 24 (Cont.)
EXPERIMENTAL SKID-RESISTANT RESURFACING

Control Section	Location	Construction Months	Mixture Type	Route	Direction and Lane	Average Coefficient of Wet Sliding Friction						
						1965	1966		1967	1968	1969	1970
							Spring	Fall				
82053	US 24 at Schoolcraft Rd, Detroit	Sept. 1965	50-lb 3BC + asbestos fiber + asphalt	US 24	NBOL	0.54	0.38	0.33	0.39	0.40	0.43	0.39
				US 24	NBCL	0.53	0.40	0.35	0.41	0.43	0.43	0.40
				US 24	NBIL	0.55	0.37	0.34	0.42	0.42	0.45	0.41
				US 24	SBOL	0.48	0.34	0.33	0.41	0.39	0.43	0.38
				US 24	SBCL	0.51	0.37	0.33	0.40	0.41	0.43	0.40
				US 24	SBIL	0.52	0.37	0.33	0.41	0.43	0.44	0.41
				Schoolcraft Rd	EBRT	0.55	0.41	0.35	0.44	0.41	0.44	0.41
				Schoolcraft Rd	EB#3	0.52	0.38	0.36	0.44	0.41	0.43	0.39
				Schoolcraft Rd	EB#2	0.54	0.38	0.34	0.45	0.43	0.46	0.43
				Schoolcraft Rd	EBIL	0.56	0.43	0.39	0.49	0.49	0.47	0.48
				Schoolcraft Rd	WB#3	0.55	0.43	0.34	0.45	0.41	0.42	0.38
				Schoolcraft Rd	WB#2	0.51	0.39	0.34	0.45	0.41	0.42	0.41
				Schoolcraft Rd	WBIL	0.55	0.46	0.36	0.47	0.47	0.47	0.48
82053	US 24 at Plymouth Rd, Detroit	Sept.-Oct. 1965	50-lb 2MS + asbestos fiber + asphalt	US 24	NBOL	0.59	0.36	0.35	0.42	0.43	0.43	0.43
				US 24	NB#3	0.59	0.37	0.36	0.41	0.43	0.45	0.42
				US 24	NB#2	0.62	0.40	0.36	0.44	0.47	0.48	0.51
				US 24	NBIL	0.62	0.40	0.38	0.45	0.45	0.46	0.55
				US 24	SBOL	0.60	0.37	0.35	0.42	0.40	0.44	0.40
				US 24	SB#3	0.62	0.39	0.35	0.43	0.43	0.46	0.42
				US 24	SB#2	0.61	0.39	0.36	0.45	0.47	0.46	0.45
				US 24	SBIL	0.64	0.42	0.37	0.50	0.52	0.46	0.59
				Plymouth Rd	EBOL	0.62	0.40	0.36	0.41	0.41	0.46	0.48
				Plymouth Rd	EBCL	0.63	0.39	0.36	0.41	0.43	0.44	0.44
				Plymouth Rd	EBIL	0.64	0.39	0.37	0.41	0.44	0.44	0.51
				Plymouth Rd	WBOL	0.63	0.40	0.38	0.46	0.47	0.46	0.49
				Plymouth Rd	WBCL	0.61	0.41	0.37	0.44	0.44	0.46	0.45
				Plymouth Rd	WBIL	0.60	0.40	0.38	0.46	0.48	0.45	0.53
82053	US 24 at W. Chicago Rd, Detroit	Oct. 1965	80-lb 2MS + 31AA + asphalt	US 24	NBOL	0.57	0.38	0.37	0.43	0.45	0.44	0.43
				US 24	NB#3	0.58	0.40	0.37	0.43	0.45	0.46	0.43
				US 24	NB#2	0.61	0.41	0.36	0.43	0.47	0.46	0.45
				US 24	NBIL	0.62	0.40	0.37	0.42	0.49	0.46	0.45
				US 24	NBLT	0.62	*	*	*	*	*	*
				US 24	SBOL	0.56	0.42	0.41	0.44	0.41	0.45	0.42
				US 24	SBCL	0.57	0.41	0.40	0.43	0.46	0.45	0.44
				US 24	SBIL	0.59	0.41	0.40	0.43	0.47	0.46	0.43
				W. Chicago Rd	EBRT	0.63	0.45	0.44	0.48	0.50	0.45	0.45
				W. Chicago Rd	EBIL	0.63	0.44	0.40	0.42	0.46	0.45	0.45
				W. Chicago Rd	WBRT	0.63	0.43	0.41	0.47	0.50	0.46	0.48
				W. Chicago Rd	WBIL	0.63	0.41	0.37	0.47	0.47	0.45	0.45
82071	US 24 at Sibley Rd, Detroit	Oct. 1965	80-lb 3NS + 31AA + asphalt	US 24	NBOL	0.50	0.41	0.34	0.44	0.45	0.49	0.44
				US 24	NBIL	0.52	0.42	0.38	0.47	0.47	0.50	0.48
				US 24	SBOL	0.51	0.43	0.39	0.46	0.47	0.52	0.50
				US 24	SBIL	0.51	0.42	0.38	0.46	0.46	0.50	0.48
				Sibley Rd	EB	0.54	0.39	0.36	0.42	0.43	0.45	0.48[8]
				Sibley Rd	WB	0.52	0.41	0.39	0.45	0.44	0.44	0.43
11031	M 139 NB at Empire Rd, Benton Harbor	Oct. 1965	80-lb 3NS (P-4) + Synopal + asphalt	M 139	NBOL	0.44	0.40	0.39	0.56	0.42	0.45	0.45
				M 139	NBIL	0.50	0.42	0.38	0.51	0.52	0.52	0.55
11031	M 139 SB at Empire Rd, Benton Harbor	Oct. 1965	80-lb 3NS (P-4) + asphalt	M 139	SBOL	0.45	0.38	0.40	0.51	0.43	0.47	0.46
				M 139	SBIL	0.48	0.44	0.41	0.52	0.51	0.50	0.52
82053	US 24 NB (Telegraph Rd) from Joy Rd to West Chicago	Aug. 1968	80-lb crushed fine aggregate	US 24	NBOL	----	----	----	----	0.59	0.44	0.41
				US 24	NB#3	----	----	----	----	0.60	0.48	0.41
				US 24	NB#2	----	----	----	----	0.61	0.46	0.42
				US 24	NBIL	----	----	----	----	0.61	0.45	0.42

(8) Tested slightly out of wheel track because of gravel graded onto pavement

TABLE 25
TEXTURED CONCRETE PAVEMENT SURFACES
Northbound I 69, Project I 13074-001

Texture Method	Test Limits (Sta. to Sta.)	Direction and Lane	Average WSF 1970
Conventional Burlap	2232+00 to 2238+00	NBOL NBIL	0.61 0.65
Longitudinal Brooming	2242+00 to 2248+00	NBOL NBIL	0.69 0.72
Transverse Combing	2253+00 to 2259+00	NBOL NBIL	0.86 0.87
Transverse Brooming	2272+00 to 2278+00	NBOL NBIL	0.76 0.79

SECTION IV

HIGH-ACCIDENT LOCATIONS

HIGH-ACCIDENT LOCATIONS

This section reports the Department's continuing program to reduce skidding accidents on wet pavement at critical locations. High-accident locations are skid tested to indicate priorities for resurfacing. In some cases, these locations are used for testing experimental skid-resistant resurfacing mixtures.

Selection of high-accident locations for this test year was made by the Traffic Division and is based on 1969 accident data. Skid tests yielded average wsf values below 0.40 at 59 percent of the 371 lanes tested in 1970. Friction levels for 5 percent of the lanes averaged below 0.30. None of the 627 high-accident lanes tested this year yielded coefficients below 0.20.

During 1970, skid tests were conducted on 29 major highway routes. Testing was dispersed throughout nine Districts, 21 Counties, and 72 separate locations. Table 26 summarizes the high-accident skid tests.

TABLE 26
HIGH-ACCIDENT LOCATIONS FOR DISTRICTS 2 THROUGH 10

District	Location	1969 Accidents: % Wet Surface	1969 Accidents: Total	Test Location	Surface Type	Average Coefficient
DISTRICT 2	Chippewa County					
	BS 75 (Ashmun) from Leroy St to Dawson St (3.140 to 3.330) City of Sault Ste. Marie (Control Section 17032)	41	32	North of Bridge		
				NBOL	BIT	0.45
				NBIL	BIT	0.44
				SBOL	BIT	0.51
				SBIL	BIT	0.43
				On Bridge		
				NBOL	CONC	0.38
				NBIL	CONC	0.35
				SBOL	CONC	0.36
				SBIL	CONC	0.35
				South of Bridge		
				NBOL	BIT	0.52
				NBCL	BIT	0.44
				SBOL	BIT	0.50
				SBIL	BIT	0.44
DISTRICT 3	Clare County					
	US 10 - M 115 from 7.010 to 7.190, City of Clare (Control Section 18022)	41	27	US 10 - M 115 @ Beech St East		
				EB	BIT	0.34
				WB	BIT	0.34
				US 10 - M 115 @ US 27 BR West		
				EB	BIT	0.35
				WB	BIT	0.36
	US 27 BR (Mission) from 0.730 to 0.920 (S of School-crest Rd to S of Brookwood Dr), City of Clare (Control Section 18031)	44	16	NBOL	BIT	0.38
				NBCL	BIT	0.31
				NBIL	BIT	0.27
				SBOL	BIT	0.50
				SBCL	BIT	0.44
				SBIL	BIT	0.32
	Grand Traverse County					
	US 31 - M 72 (Munson) from Airport Access Rd to Avenue B (3.100 to 3.300) City of Traverse City (Control Section 28013)	50	20	EBOL	CONC	0.31
				EBIL	CONC	0.29
				WBOL	CONC	0.33
				WBIL	CONC	0.31
	Manistee County					
	US 31 (Cypress) from Fifth St to Second St (4.680 to 4.880) City of Manistee (Control Section 51011)	41	17	NBOL	CONC	0.27
				NBIL	CONC	0.30
				SBOL	CONC	0.32
				SBIL	CONC	0.30
DISTRICT 4	Emmet County					
	US 31 @ Penn RR crossing just E of E City Limits of Petoskey (8.260 to 8.470) (Control Section 24011)	17	14	NB	BIT	0.33
				SB	BIT	0.34
DISTRICT 5	Clinton County					
	US 27 (Whitmore) from Cass St to M 21 (16.020 to 16.112), City of St. Johns (Control Section 19031)	43	21	NBOL	CONC	0.32
				NBIL	CONC	0.34
				SBOL	CONC	0.33
				SBIL	CONC	0.33
	Kent County					
	US 131, N and S of 44th St (8.000 to 8.200), City of Wyoming (Control Section 41131)	39	33	NBOL	CONC	0.41
				NBIL	CONC	0.44
				SBOL	CONC	0.41
				SBIL	CONC	0.46
	US 131 @ M 11 (28th St) (10.150 to 10.350), City of Wyoming (Control Section 41131)	45	20	NBOL	CONC	0.39
				NBCL	CONC	0.41
				NBIL	CONC	0.48
				SBOL	CONC	0.41
				SBIL	CONC	0.44
	US 131 @ Burton St (11.150 to 11.350), City of Grand Rapids (Control Section 41131)	38	34	NBOL	CONC	0.39
				NBCL	CONC	0.44
				NBIL	CONC	0.47
				SBOL	CONC	0.40
				SBCL	CONC	0.42
				SBIL	CONC	0.46
	US 131 S of Hall St (11.850 to 12.050), City of Grand Rapids (Control Section 41131)	36	22	NBOL	CONC	0.41
				NBCL	CONC	0.40
				NBIL	CONC	0.44
				SBOL	CONC	0.43
				SBCL	CONC	0.42
				SBIL	CONC	0.49
	US 131 @ Wealthy St (13.140 to 13.340), City of Grand Rapids (Control Section 41131)	40	60	NBOL	CONC	0.38
				NBCL	CONC	0.40
				NBIL	CONC	0.36
				SBOL	CONC	0.36
				SBCL	CONC	0.39
				SBIL	CONC	0.39
	US 131 @ NB Jct US 131 BR Exit (13.350 to 13.550), City of Grand Rapids (Control Section 41131)	55	29	NBOL	CONC	0.29
				NBCL	CONC	0.32
				NBIL	CONC	0.34
				SBOL	CONC	0.29
				SBCL	CONC	0.30
				SBIL	CONC	0.32

TABLE 26 (Cont.)
HIGH-ACCIDENT LOCATIONS FOR DISTRICTS 2 THROUGH 10

District	Location	1969 Accidents % Wet Surface	1969 Accidents Total	Test Location	Surface Type	Average Coefficient
DISTRICT 5 (CONT.)	Kent County Cont.					
	US 131 @ Grandville St (13.570 to 13.760), City of Grand Rapids (Control Section 41131)	56	25	NBOL	CONC	0.34
				NBCL	CONC	0.34
				NBIL	CONC	0.31
				SBOL	CONC	0.30
				SBCL	CONC	0.34
				SBIL	CONC	0.36
	US 131 S from Pearl St (13.980 to 14.180), City of Grand Rapids (Control Section 41131)	45	20	NBOL	CONC	0.38
				NBCL	CONC	0.40
				NBIL	CONC	0.39
				SBOL	CONC	0.39
				SBCL	CONC	0.39
				SBIL	CONC	0.44
	Ottawa County					
	US 31 (Beacon Blvd) from Grant St to Franklin St (6.310 to 6.480), City of Grand Haven (Control Section 70015)	50	20	NBOL	CONC	0.32
				NBIL	CONC	0.36
				SBOL	CONC	0.31
				SBIL	CONC	0.37
DISTRICT 6	Genesee County					
	M 121 (Bristol) from 2.640 to 2.840 (E & W of I 75 - US 23) Control Section 25061	45	20	EBOL	CONC	0.30
				EBIL	CONC	0.32
				EB merging lane from SB I 75 (Ramp)	CONC	0.35
				WBOL	CONC	0.27
				WBCL	CONC	0.30
				WBIL	CONC	0.35
	M 54 (Dort Hwy) from West Blvd (08.110) to Pierson Rd (08.330), City of Flint Control Section 25072	45	20	West Blvd to N of Stewart		
				NBOL	CONC	0.36
				NBIL	BIT	0.45
				SBOL	CONC	0.33
				SBIL	BIT	0.45
				N of Stewart to Pierson Rd		
				NBOL	BIT	0.33
				NBIL	BIT	0.39
				SBOL	BIT	0.33
				SBIL	BIT	0.38
	Midland County					
	US 10 BR - M 20 EB (Buttles) & WB (Indian) from Ashman (80.180 to Townsend St (80.360), City of Midland Control Section 56023	48	25	EBOL	CONC	0.32
				EBCL	CONC	0.32
				EBIL	CONC	0.34
				WBOL	BIT	0.39
				WBCL	BIT	0.42
				WBIL	BIT	0.41

District	Location	1969 Accidents % Wet Surface	1969 Accidents Total	Test Location	Surface Type	Average Coefficient
DISTRICT 6 (CONT.)	Saginaw County					
	M 46 (Rust) from 8.500 to 8.660 (Newton St to E of Fordney St), City of Saginaw Control Section 73062	45	20	EBOL	CONC	0.37
				EBIL	CONC	0.36
				WBOL	CONC	0.34
				WBIL	CONC	0.38
	M 81 (State) from 4.810 to 4.970 (E & W of Brockway Rd) Control Section 73073	42	33	EBOL	CONC	0.33
				EBCL	CONC	0.34
				EBIL	BIT	0.40
				WBOL	CONC	0.31
				WBCL	CONC	0.34
				WBIL	BIT	0.44
	M 81 EB (Genesee) from Niagara St to Water St (72.770 to 72.960 includes Saginaw River Bridge) City of Saginaw Control Section 73073	43	23	W of Bascule (Steel Deck)		
				EBOL	BIT	0.34
				EBCL	BIT	0.36
				EBIL	BIT	0.37
				WB	BIT	0.35
				E of Bascule (Steel Deck)		
				EBOL	BIT	0.31
				EBCL	BIT	0.35
				EBIL	BIT	0.34
				WB	BIT	0.33
DISTRICT 7	Calhoun County					
	M 89 (Michigan) from Everett to Miller (3.420 to 3.620), City of Battle Creek (Control Section 13061)	41	22	EBOL	(1)	0.34
				EBIL	BIT	0.37
				WBOL	CONC	0.32
				WBIL	BIT	0.43
	M 37 (VanBuren--formerly BL 94) @ Washington (6.240), City of Battle Creek (Control Section 13061)	NA	NA	WB#3	BIT	0.48
				WB#2	BIT	0.45
				WBIL	BIT	0.48
	BL 94 (Dickman) @ Washington (7.280 to 7.440), City of Battle Creek (Control Section 13121)	50	30	EBOL	BIT	0.42
				EBIL	BIT	0.45
				WBOL	BIT	0.38
				WBIL	BIT	0.43
	BL 94 EB (Main) from Michigan to Westnedge (3.820 to 4.000), City of Kalamazoo (Control Section 39041)	60	40	EB#5	BIT	0.32
				EB#4	BIT	0.33
				EB#3	BIT	0.35
				EB#2	BIT	0.40
				EBIL	BIT	0.34
	M 43 (W. Main) from Cherokee to Nichols (7.00 to 7.230) (Control Section 39081)	42	26	EBOL	CONC	0.31
				EBIL	CONC	0.29
				WBOL	CONC	0.27
				WBIL	CONC	0.31

(1) Outside wheeltrack - CONC and inside wheeltrack - BIT

TABLE 26 (Cont.)
HIGH-ACCIDENT LOCATIONS FOR DISTRICTS 2 THROUGH 10

District	Location	1969 Accidents % Wet Surface	1969 Accidents Total	Test Location	Surface Type	Average Coefficient
DISTRICT 7 (CONT.)	Calhoun County Cont.					
	M 43 (W. Main) from Cherry Hill Rd to Coolidge Rd (7.250 to 7.440) (Control Section 39081)	50	30	EBOL	CONC	0.28
				EBIL	CONC	0.32
				WBOL	CONC	0.32
				WBIL	CONC	0.30
	M 43 (W. Main) from Pinehurst to Claredon (7.760 to 7.960) (Control Section 39081)	45	20	EBOL	CONC	0.30
				EBIL	CONC	0.30
				WBOL	CONC	0.31
				WBIL	CONC	0.31
DISTRICT 8	Eaton County					
	M 43 (Saginaw) from Bretton Wood to Harriet (6.430 to 6.590) Control Section 23042	50	26	EBOL	CONC	0.37
				EBIL	BIT	0.42
				WBOL	CONC	0.31
				WBIL	BIT	0.42
	Ingham County					
	M 99 (Logan) from Berten to Britten, (4.850 to 5.050), City of Lansing Control Section 33011	41	37	NBOL	BIT	0.41
				NBIL	BIT	0.34
				SBOL	BIT	0.32
				SBIL	BIT	0.33
	M 99 (Logan) from Alsdorf to the Grand River Bridge (5.060 to 5.240), City of Lansing Control Section 33011	47	30	NBOL	BIT	0.44
				NBIL	BIT	0.37
				SBOL	BIT	0.31
				SBIL	BIT	0.32
	US 27 - M 78 BR SB (Cedar) at Michigan (60.540 to 60.570), City of Lansing Control Section 33033	21	31	SBOL	BIT	0.39
				SBCL	BIT	0.37
				SBIL	BIT	0.39
	US 27 NB (Larch) at Grand River Ave (00.330 to 00.450) City of Lansing Control Section 33034	22	31	NBOL	BIT	0.43
				NB#3	BIT	0.39
				NB#2	BIT	0.38
				NBIL	BIT	0.41
	US 27 (North East St.) from Thomas to Banghart St (1.200 to 1.380), City of Lansing Control Section 33034	42	31	NBOL	BIT	0.41
				NBIL	BIT	0.46
				SBOL	BIT	0.41
				SBIL	BIT	0.47
	US 27 SB (Cedar) at Grand River Ave (60.450 to 60.570), City of Lansing Control Section 33034	35	36	SBOL	CONC	0.31
				SBCL	CONC	0.32
				SBIL	CONC	0.33
	M 43 (Grand River) from Wood to Fairview (80.910 to 81.100), City of Lansing Control Section 33042	42	26	WBOL	BIT	0.28
				WB#3	BIT	0.35
				WB#2	BIT	0.33
				WBIL	BIT	0.34
DISTRICT 8 (CONT.)	Ingham County Cont.					
	M 43 (Oakland) from Sycamore to N Chestnut (82.060 to 82.220), City of Lansing Control Section 33061	48	21	WBOL	CONC	0.34
				WBCL	CONC	0.35
				WBIL	CONC	0.35
	Jackson County					
	US 127 BR - M 50 (Clinton and West) from Commonwealth to Dewey (0.230 to 0.430), City of Jackson Control Section 38072	52	23	NBOL	CONC	0.34
				NBIL	CONC	0.40
				SBOL	CONC	0.31
				SBOL	BIT	0.40
				SBIL	BIT	0.43
	US 127 BR - M 50 (West) from Argyle to North (0.710 to 0.910), City of Jackson Control Section 38072	41	22	NBOL	CONC	0.27
				NBIL	BIT	0.43
				SBOL	CONC	0.30
				SBIL	BIT	0.41
	BL 94 (Washington) from Milwaukee to Perrien (1.340 to 1.540), City of Jackson Control Section 38083	43	40	EBOL	BIT	0.34
				EBIL	BIT	0.33
				WBOL	BIT	0.34
				WBIL	BIT	0.32
	BL 94 (Michigan) from State to East (1.580 to 1.780), City of Jackson Control Section 38083	42	38	EBOL	BIT	0.47
				EBIL	BIT	0.49
				WBOL	BIT	0.47
				WBIL	BIT	0.47
				EBOL	BIT	0.30(2)
				EBIL	BIT	0.30(2)
				WBOL	BIT	0.32(2)
				WBIL	BIT	0.31(2)
	BL 94 (Washington) from Mechanic to Otsego (70.440 to 70.640), City of Jackson Control Section 38083	41	22	Mechanic to Francis		
				EBOL	CONC	0.34
				EBCL	CONC	0.28
				EBIL	CONC	0.33
				Francis to Otsego		
				EBOL	CONC	0.33
				EBCL	CONC	0.29
				EBIL	CONC	0.36
	Washtenaw County					
	M 17 (Washtenaw) from Roosevelt Blvd to Fairview Circle (2.560 to 2.760), City of Ypsilanti Control Section 81081	55	20	EB	BIT	0.40
				WB	BIT	0.38

(2) Only 1 test conducted in stopping area at East St.

TABLE 26 (Cont.)
HIGH-ACCIDENT LOCATIONS FOR DISTRICTS 2 THROUGH 10

DISTRICT 9

Location	1969 Accidents % Wet Surface	1969 Accidents Total	Test Location	Surface Type	Average Coefficient
Macomb County					
M 59 (Hall) from VanDyke to Grant Park Blvd (0.000 to 0.200), City of Utica Control Section 50022	40	42	EBOL	CONC	0.30
			EBIL	BIT	0.39
			WBOL	CONC	0.31
			WBIL	BIT	0.42
M 97 (Groesbeck) at Frazho Rd (3.020 to 3.210) City of Warren Control Section 50031	36	36	NBOL	CONC	0.33
			NBIL	CONC	0.33
			SBOL	CONC	0.32
			SBIL	CONC	0.32
M 97 (Groesbeck) from Hayes Rd NE 0.2 mi, (3.670 to 3.880), City of Roseville Control Section 50031	40	40	NBOL	CONC	0.31
			NBIL	CONC	0.32
			SBOL	CONC	0.31
			SBIL	CONC	0.32
M 97 (Groesbeck) at Martin Rd (3.970 to 4.170), City of Roseville Control Section 50031	42	43	NBOL	CONC	0.30
			NBIL	CONC	0.32
			SBOL	CONC	0.30
			SBIL	CONC	0.32
M 97 (Groesbeck) from Garfield to Thirteen Mile Rd (5.700 to 5.920), City of Roseville Control Section 50031	39	57	NBOL	CONC	0.31
			NBIL	CONC	0.30
			NBOL	BIT	0.40
			NBIL	BIT	0.42
			SBOL	BIT	0.39
			SBIL	BIT	0.42
			SBOL	CONC	0.32
			SBIL	CONC	0.33
M 97 (Groesbeck) at Sixteen Mile Rd (9.370 to 9.570) Clinton Twp Control Section 50031	36	39	NBOL	BIT	0.41
			NBIL	BIT	0.46
			SBOL	BIT	0.46
			SBIL	BIT	0.44
			NBOL	BIT	0.30[a]
			NBIL	BIT	0.40[a]
			SBOL	BIT	0.37[a]
			SBIL	BIT	0.42[a]
US 25 (Gratiot) from Ash to Park (0.810 to 1.250), City of East Detroit Control Section 50051	35	131	NBOL	BIT	0.42
			NBCL	BIT	0.46
			NBIL	BIT	0.45
			NBIL	CONC	0.41
			SBOL	CONC	0.36
			SBCL	CONC	0.38
			SBIL	CONC	0.35
US 25 SB from Wellington to Harrington Blvd (62.240 to 62.440), City of Mt. Clemens Control Section 50051	38	37	SBOL	CONC	0.36
			SB#2	CONC	0.33
			SB#3	CONC	0.32
			SBIL	CONC	0.34
			SB#2	BIT	0.44
			SB#3	BIT	0.44

[a] Single test conducted at stopping area between the median dividing EB and WB 16 Mile Rd.

DISTRICT 9 (CONT.)

Location	1969 Accidents % Wet Surface	1969 Accidents Total	Test Location	Surface Type	Average Coefficient
Oakland County					
M 59 (Huron) from 11.140 to 11.340 (curve W of Fisk Rd), Control Section 63041	38	34	EB	BIT	0.39
			WB	BIT	0.47
M 59 (Huron) from Seba Dr (16.000) to Pontiac Lake Rd (16.230) Control Section 63041	35	48	EBOL	BIT	0.44
			EBIL	BIT	0.49
			WBOL	BIT	0.43
			WBIL	BIT	0.52
			EBOL	CONC	0.30
			EBIL	CONC	0.34
			WBOL	CONC	0.32
			WBIL	CONC	0.31
M 59 (Huron) from Genesee to Waldo & Chippewa (19.500 to 19.700), City of Pontiac Control Section 63041	41	41	EBOL	CONC	0.36
			EBIL	CONC	0.37
			WBOL	CONC	0.36
			WBCL	CONC	0.37
			WBIL	CONC	0.36
M 59 (Huron) from Franklin Blvd to State St (20.480 to 20.700), City of Pontiac Control Section 63041	47	30	EBOL	BIT	0.44
			EBIL	BIT	0.44
			WBOL	BIT	0.43
			WBIL	BIT	0.42
US 10 (Hunter Blvd) from Oak to Woodward (3.950 to 4.150), City of Birmingham Control Section 63051	39	38	NBOL	BIT	0.51
			NB#3	BIT	0.52
			NB#2	BIT	0.51
			NBIL	BIT	0.54
			SBOL	BIT	0.60
			SB#3	BIT	0.51
			SB#2	BIT	0.58
			SBIL	BIT	0.57
US 10 (Telegraph) from Ruth to Menominee (2.640 to 2.840), City of Pontiac Control Section 63052	37	35	NBOL	BIT	0.41
			NBCL	BIT	0.41
			NBIL	BIT	0.45
			SBOL	BIT	0.43
			SBCL	BIT	0.41
			SBIL	BIT	0.47
BL 75 - M 24 BR (Perry) from Fairgrove to Eddy Ct (0.090 to 0.290), City of Pontiac Control Section 63091	40	30	NBOL	BIT	0.44
			NBIL	BIT	0.43
			SBOL	BIT	0.44
			SBIL	BIT	0.44
BL 75 - M 24 BR (Perry) from Parkwood to Scottwood (1.710 to 1.880), City of Pontiac Control Section 63091	45	31	NBOL	BIT	0.46
			NBIL	BIT	0.47
			SBOL	CONC	0.38
			SBIL	CONC	0.41
M 24 (Lapeer Rd) at Clarkston Rd (6.010 to 6.210) Control Section 63112	45	38	NBOL	BIT	0.31
			NBIL	BIT	0.33
			SBOL	BIT	0.29
			SBIL	BIT	0.28

TABLE 26 (Cont.)

HIGH-ACCIDENT LOCATIONS FOR DISTRICTS 2 THROUGH 10

DISTRICT 9 (CONT.)

Location	1969 Accidents: % Wet Surface	1969 Accidents: Total	Test Location	Surface Type	Average Coefficient
Oakland County Cont.					
BL 75 - US 10 BR (Woodward) from Raeburn to Turk, (1.820 to 2.000), City of Pontiac Control Section 63151	46	37	NBOL	BIT	0.46
			NBCL	BIT	0.42
			NBIL	BIT	0.44
			SBOL	BIT	0.44
			SBCL	BIT	0.45
			SBIL	BIT	0.41
M 39 (Southfield) through BS 696 Interchange (0.850 to 1.030), City of Southfield Control Section 63171	38	40	EB 696 BS to SB M 39 Ramp		
			SBOL	CONC	0.37
			SBIL	CONC	0.43
			M 39 through BS 696 Interchange		
			NBOL	CONC	0.38
			NBCL	CONC	0.37
			NBIL	CONC	0.36
			SBOL	CONC	0.38
			SBIL	CONC	0.42
			NB M 39 to WB 696 BS Ramp		
			WBOL	CONC	0.32
			WBIL	CONC	0.27
I 75 from John R. to Nine Mile Rd (1.060 to 1.270), City of Hazel Park Control Section 63174	47	34	NBOL	CONC	0.41
			NB#3	CONC	0.34
			NB#2	CONC	0.42
			NBIL	CONC	0.41
			SBOL	CONC	0.35
			SB#3	CONC	0.31
			SB#2	CONC	0.37
			SBIL	CONC	0.38
I 75 from Maple Rd to M 150 (Rochester Rd) (7.530 to 8.712), City of Troy Control Section 63174	22	52	NBOL	CONC	0.43
			NBCL	CONC	0.47
			NBIL	CONC	0.50
			SBOL	CONC	0.40
			SBCL	CONC	0.44
			SBIL	CONC	0.46
I 75 from Livernois Rd to the N limits of the Big Beaver Rd interchange (9.640 to 10.550), City of Troy Control Section 63174	55	48	NBOL	CONC	0.40
			NBCL	CONC	0.43
			NBIL	CONC	0.53
			SBOL	CONC	0.41
			SBCL	CONC	0.43
			SBIL	CONC	0.46
I 75 from East Long Lake Rd to 0.25 mile W of Crooks Rd (12.250 to 13.700), City of Troy Control Section 63174	36	29	NBOL	CONC	0.40
			NBCL	CONC	0.47
			NBIL	CONC	0.54
			SBOL	CONC	0.46
			SBCL	CONC	0.48
			SBIL	CONC	0.51

District	Location	1969 Accidents: % Wet Surface	1969 Accidents: Total	Test Location	Surface Type	Average Coefficient
DISTRICT 9 (CONT.)	St. Clair County					
	US 25 BR (Pine Grove) from McPherson to 10th and Scott (0.170 to 0.370) City of Port Huron Control Section 77091	35	37	NBOL	BIT	0.41
				NBIL	BIT	0.44
				SBOL	BIT	0.43
				SBIL	BIT	0.42
				SBOL	BIT	0.33(a)
				SBIL	BIT	0.38(a)
DISTRICT 10	Monroe County					
	US 25 (Monroe) from Third To Front (14.580 to 14.780), City of Monroe (Control Section 58071)	46	35	NBOL	BIT	0.29
				NBIL	BIT	0.32
				SBOL	BIT	0.33
				SBIL	BIT	0.29
	Wayne County					
	US 12 (Michigan Ave) at M 153 (Wyoming Ave) (6.100 to 6.250), Cities of Dearborn and Detroit (Control Section 82062)	39	36	EBOL	BIT	0.37
				EBCL	BIT	0.40
				EBIL	BIT	0.40
				WBOL	BIT	0.41
				WBCL	BIT	0.38
				WBIL	BIT	0.40
	I 75 from Northline Rd to Goddard Rd (10.546 to 11.900), City of Southgate (Control Section 82191)	50	51	NBOL	CONC	0.35
				NBCL	CONC	0.45
				NBIL	CONC	0.39
				SBOL	CONC	0.37
				SBCL	CONC	0.48
				SBIL	CONC	0.45
	M 39 (Southfield) from I 75 to Abbott (0.210 to 0.370), City of Lincoln Park (Control Section 82192)	36	53	NBOL	CONC	0.34
				NBCL	CONC	0.34
				NBIL	CONC	0.33
				SBOL	CONC	0.32
				SBCL	CONC	0.33
				SBIL	CONC	0.34

(a) Only 1 test conducted in stopping area between 10th and Scott Sts.

SECTION V

SPECIAL REQUEST TESTS

SPECIAL REQUEST TESTS

During the course of the year, requests for skid tests are received from field personnel or through the Design, Maintenance, Traffic, or Testing and Research Divisions. These requests receive priority considerations during scheduling of skid tests. Friction data are forwarded to the person or agency initiating the request as soon as possible after completion of field measurements. Table 27 contains skid test data resulting from special requests received during 1970.

TABLE 27
SPECIAL REQUEST TESTS

Special Request No.*	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
1	S04 of 81063	Wiard Rd over EB US 12	CONC	NBOL	0.48
			CONC	NBCL	0.40
			CONC	NBIL	0.34
			BIT	NBCL (approach)	0.51
			BIT	NBCL (departure)	0.52
2	S04 of 81063	Wiard Rd over EB US 12	CONC	NBOL	0.40
			CONC	NBCL	0.31
			CONC	NBIL	0.25
3	Ms 25081-006	M 21 from E of Dye Rd E to Media St in Flint	SFSA	EBOL	0.53
			SFSA	EBIL	0.57
			SFSA	WBOL	0.49
			SFSA	WBIL	0.58
3	M 32021-004	M 142 from M 25 E to Pigeon	SFSA	EB	0.67
			SFSA	WB	0.66
3	Mb 79051-007	M 24 from M 46 N to Frank St in Caro	SFSA	NB	0.66
			SFSA	SB	0.65
3	Mb 46061-010	US 12 from E of M 50 E to E of M 124	SFSA	EB	0.60
			SFSA	WB	0.67
3	M 76041-005	M 71 from M 78 N to S limits of Corunna	SFSA	NB	0.63
			SFSA	SB	0.60
3	Ms 77033-008	US 25 (Lake Shore Pike) from Lynburner Rd N to N of Myrtle Rd	SFSA	NB	0.56
			SFSA	SB	0.58
3	Mns 88500-004	US 24 (Telegraph Rd) from Exeter Rd to Long Lake Rd	SFSA	NBOL	0.51
			SFSA	NBIL	0.50
			SFSA	SBOL	0.51
			SFSA	SBIL	0.54
3	Ms 09011-003	M 84 - I 75 BL from SW of Ziegler Rd NE'ly to M 13	SFSA	NB	0.59
			SFSA	SB	0.60
3	Ms 11012-006	I 94 BL (Main St) from State St NE'ly to Jones St in Flint	SFSA	NBOL	0.50
			SFSA	NBIL	0.55
			SFSA	SBOL	0.54
			SFSA	SBIL	0.56
3	Ms 77032-007	US 25 BR from SW of M 29 in Marysville NE'ly to Dove St in Port Huron	SFSA	NBOL	0.52
			SFSA	NBIL	0.57
			SFSA	SBOL	0.48
			SFSA	SBIL	0.54
3	Mb 79062-003	M 81 from SW of Green Rd NE'ly and E'ly to M 53 in Cass City	SFSA	EB	0.64
			SFSA	WB	0.64
3	Ms 11013-010	I 94 (Main St) from M 139 N (Paw-Paw Ave) E'ly to M 139 S (Fair Ave)	SFSA	EBOL	0.47
			SFSA	EBIL	0.47
			SFSA	WBOL	0.43
			SFSA	WBIL	0.46

* Numbered in order requests are received. TR prefix to number indicates a TOPICS request.

TABLE 27 (Cont.)
SPECIAL REQUEST TESTS

Special Request No. *	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
3	Mb 38071-010	M 50 from E of Hand Rd in Lenawee Co, W'ly & N'ly to Stoney Lake Rd, in Jackson Co, omitting at US 12 and at the divided roadway in Brooklyn	SFSA	NB	0.64
			SFSA	SB	0.67
3	Mb 46061-011	US 223 BR - M 52 from Nelson St to Merrick St in Adrian	SFSA	NBOL	0.56
			SFSA	NBIL	0.54
			SFSA	SBOL	0.55
			SFSA	SBIL	0.58
3	Mb 46061-011	US 223 BR at W limits of Adrian	SFSA	EB	0.58
			SFSA	WB	0.54
3	Mb 46101-007	US 12 from E of Pentacost Hwy E'ly to the Lenawee-Washtenaw Co Line, omitting from 350 ft E of the Raisin River in Clinton, E'ly to the E village limits of Clinton	SFSA	EB	0.56
			SFSA	WB	0.58
3	Ms 63052-021	US 10 (Telegraph Rd) from NW of Bataan Rd to SE of Bataan Rd	SFSA	SBOL	0.53
3	Ms 69014-012	SB I 75 from 2400 ft N of old US 27 N'ly 2800 ft (N of Vanderbilt)	SFSA	SBOL	0.60
			SFSA	SBIL	0.65
3	Mb 76041-006	M 21 (Main St) from W city limits of Owosso (Chestnut St) E'ly to the E city limits of Owosso (Gould St), omitting from Shiawassee River to Ball St	SFSA	EBOL	0.54
			SFSA	EBIL	0.55
			SFSA	WBOL	0.57
			SFSA	WBIL	0.58
3	Mb 79031-007	M 15 (State St) from N of S village limits of Millington, N'ly to N of Ellis Rd	SFSA	NB	0.53
			SFSA	SB	0.51
3	Ms 25071-007	M 54 at M 54 BR	SA	NBOL	0.57
			SA	NBIL	0.62
			SA	SBOL	0.56
			SA	SBIL	0.61
			SA	WBOL	0.61
			SA	WBIL	0.60
3	Mb 38061-008	M 60 from Spring St in Concord, W to Homer Rd	SA	EB	0.60
			SA	WB	0.57
3	Mb 38061-008	M 60 from Homer Rd W to the Calhoun-Jackson Co. line	SA	EB	0.62
			SA	WB	0.62
3	Mb 58042-008	M 50 from US 24 to US 25 in Monroe	SA	EB	0.46
			SA	WB	0.49
3	Mb 38061-008	M 50 from Stoney Lake Rd N & W to South City limits of Jackson, omitting at US 127 interchange	SA	EB	0.66
			SA	WB	0.65
3	Mb 82052-037	US 24 from Pardee Rd S to Carter Rd	SA	NBOL	0.53
			SA	NBIL	0.57
			SA	SBOL	0.54
			SA	SBIL	0.53

TABLE 27 (Cont.)
SPECIAL REQUEST TESTS

Special Request No. *	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
3	Mb 46062-007	US 223 from bridge over Raisin River in Palmyra SE to SE of North Lane St in Blissfield, omitting from High St to Pearl St in Blissfield	SA	EB	0.59
			SA	WB	0.59
3	Ms 82053-045	US 24 at Warren Rd	SA	NBOL	0.36
			SA	NB#3	0.30
			SA	NB#2	0.32
			SA	NBIL	0.39
			SA	SBOL	0.30
			SA	SBCL	0.35
			SA	SBIL	0.40
3	Ms 82053-045	US 24 at Joy Rd	SA	NBOL	0.54
			SA	NB#3	0.46
			SA	NB#2	0.42
			SA	NBIL	0.48
4	Mb 80071-005	M 40,2.2 mi. N of Paw-Paw; S from 40th Ave	SFSA	NB	0.54
			SFSA	SB	0.53
4	Mb 80071-005	M 43,0.7 mi. W of M 40	BA	EB	0.32
			BA	WB	0.30
4	Mb 80071-005	M 43, 6.0 mi. W of M 40	BA	EB	0.84
			BA	WB	0.31
4	Mb 80071-005	M 43, 6.3 mi. W of M 40	BA	EB	0.32
			BA	WB	0.20
4	Mb 80071-005	M 43, 6.4 mi. W of M 40	BA	EB	0.28
			BA	WB	0.21
4	Mb 80071-005	Five intermittent patches on M 40 SW of Decatur (numbered 1 to 5 from NE to SW)			
		No. 1	BA	NB	0.20
			BA	SB	0.20
		No. 2	BA	NB	0.19
			BA	SB	0.31
		No. 3	BA	NB	0.31
			BA	SB	0.32
		No. 4	BA	NB	0.38
			BA	SB	0.35
		No. 5	BA	NB	0.26
			BA	SB	0.36
4	Mb 80071-005	M 119 from M 216 S, the entire length of the curb and gutter section in Marcellus	BA	NB	0.49
			BA	SB	0.50
5	Mtb 20051-002 Mb 72093-002	M 18 - M 76, S from old US 27	BA	NB	0.43
			BA	SB	0.49
5	Mtb 20051-002 Mb 72092-002	M 18 - M 76, 0.5 mi. N of Fletcher Rd	BA	NB	0.42
			BA	SB	0.39

TABLE 27 (Cont.)
SPECIAL REQUEST TESTS

Special Request No. *	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
5	Mtb 20051-002 Mb 72092-002	M 18 - M 76, adjacent to roadside park	BA BA	NB SB	0.40 0.43
5	Mtb 20051-002 Mb 72092-002	M 18 - M 76, 0.5 mi. SE of Johnson Rd	BA BA	NB SB	0.42 0.45
6	Mb 80071-005	M 40, 2.2 mi. N of Paw-Paw, S from 40th Ave	SFSA SFSA	NB SB	0.59 0.56
6	Mb 80071-005	M 43, 0.7 mi. W of M 40	K&S BA K&S BA	EB WB	0.38 0.34
6	Mb 80071-005	M 43, 6.0 mi. W of M 40	K&S BA K&S BA	EB WB	0.38 0.41
6	Mb 80071-005	M 43, 6.3 mi. W of M 40	K&S BA K&S BA	EB WB	0.42 0.41
6	Mb 80071-005	M 43, 6.4 mi. W of M 40	K&S BA K&S BA	EB WB	0.34 0.38
6	Mb 80071-005	Five intermittent patches on M 40 SW of Decatur (Numbered 1 to 5 from NE to SW)			
		No. 1	K&S BA K&S BA	NB SB	0.30 0.24
		No. 2	K&S BA K&S BA	NB SB	0.30 0.29
		No. 3	K&S BA K&S BA	NB SB	0.28 0.29
		No. 4	K&S BA K&S BA	NB SB	0.34 0.30
		No. 5	K&S BA K&S BA	NB SB	0.40 0.33
6	Mb 80071-005	M 119 from M 216 S, the entire length of the curb and gutter section in Marcellus	BA BA	NB SB	0.44 0.46
7	Mb 23052-002	M 50 at Fawn Lane Rd (1st location W of US 127)	BC BC	EB WB	0.22 0.22
7	Mb 23052-002	M 50 at Blackman Rd (2nd location W of US 127)	BC BC	EB WB	0.29 0.25
7	Mb 23052-002	M 50 at Woodard Rd (3rd location W of US 127)	BC BC	EB WB	0.37 0.43
7	Mb 23052-002	M 50 through Tompkins Center (4th location W of US 127)	BC BC	EB WB	0.35 0.30
7	Mb 23052-002	M 50 from M 43 SE to Sanborn Rd	BC BC	EB WB	0.50 0.54
7	Mb 23052-002	M 50 at Round Lake Rd	BC BC	EB WB	0.51 0.53

TABLE 27 (Cont.)
SPECIAL REQUEST TESTS

Special Request No. *	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
7	Mb 23052-002	M 50 at Gresham Rd	BC	EB	0.50
			BC	WB	0.44
7	Mb 23052-002	M 50 SE from Vermontville Hwy	BC	EB	0.39
			BC	WB	0.45
7	Mb 23052-002	M 50 at "S" curve S of Wheaton Rd	BC	EB	0.41
			BC	WB	0.44
7	Mb 23052-002	M 50, N of Maple St, near N city limits of Charlotte	BC	EB	0.30
			BC	WB	0.30
7	Mb 23052-002	M 50 E from Flanders Rd, E of Charlotte	BC	EB	0.47
			BC	WB	0.51
7	Mb 23052-002	M 50 at Whittum Rd	BA	EB	0.46
			BA	WB	0.45
8	Mb 23052-002	M 50 at Fawn Lane Rd (1st location W of US 127)	K&S BC	EB	0.33
			K&S BC	WB	0.32
8	Mb 23052-002	M 50 at Blackman Rd (2nd location W of US 127)	K&S BC	EB	0.26
			K&S BC	WB	0.33
8	Mb 23052-002	M 50 at Woodard Rd (3rd location W of US 127)	BC	EB	0.40
			BC	WB	0.47
8	Mb 23052-002	M 50 through Tompkins Center (4th location W of US 127)	BC	EB	0.38
			BC	WB	0.31
9	B01 of 09042	I 75 from M 46 N to the Zilwaukee Bridge, 4 locations:			
		No. 1 - M 46 North	CONC	NBOL	0.40
			CONC	NBCL	0.48
			CONC	NBIL	0.57
			CONC	SBOL	0.40
			CONC	SBIL	0.44
		No. 2 - vicinity of I 675 interchange	CONC	NBOL	0.43
			CONC	NBIL	0.47
			CONC	SBOL	0.41
			CONC	SBIL	0.39
		No. 3 - North of C&O RR bridge	CONC	NBOL	0.43
			CONC	NBIL	0.50
			CONC	SBOL	0.44
			CONC	SBIL	0.52
		No. 4 - S of bridge over Saginaw River (Zilwaukee Bridge)	BIT	NBOL	0.45
			BIT	NBIL	0.44
			BIT	SBOL	0.43
			BIT	SBIL	0.48
10	I 33044-057	I 496 from Capitol Ave to W of Grand Ave	CONC	EBOL	0.57
			CONC	EBIL	0.53

TABLE 27 (Cont.)
SPECIAL REQUEST TESTS

Special Request No. *	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
11	29011, C2	US 27 SB, at left hand curve area S of Washington Rd, E of Ithaca. Three locations:			
		No. 1 - Washington Rd S to Ann Arbor RR	CONC CONC	SBOL SBIL	0.44 0.56
		No. 2 - Ann Arbor RR S into left hand curve	BIT BIT	SBOL SBIL	0.62 0.63
		No. 3 - S of bit wedge, proceeding out of curve	CONC CONC	SBOL SBIL	0.37 0.48
12	S 04 of 81063	Wiard Rd structure over EB US 12, bridge deck	CONC CONC CONC	NBOL NBCL NBIL	0.42 0.30 0.27
13	Mb 23052-002	M 50 at Fawn Lane Rd (1st location W of US 127)	K&S BIT	EB WB	0.41 0.42
13	Mb 23052-002	M 50 at Blackman Rd (2nd location W of US 127)	K&S BIT K&S BIT	EB WB	0.33 0.37
14	Mb 58053-003	US 24 - US 25, 300 ft N of Carleton Rockwood Rd, four locations:			
		No. 1 - US 24 - US 25 300 ft N of Carleton Rockwood Rd	BIT CONC BIT CONC BIT CONC BIT CONC	NBOL NBIL SBOL SBIL	0.45 0.52 0.49 0.49
		No. 2 - US 24 - US 25, S of Newberg Rd	BIT CONC BIT CONC BIT CONC	NBOL NBIL SBOL SBIL	0.56 0.61 0.54 0.59
		No. 3 - US 24 - US 25 at Will Carleton Rd and Huron River Drive, Monroe and Wayne Co's.	BIT CONC BIT CONC BIT CONC BIT CONC	NBOL NBIL SBOL SBIL	0.48 0.53 0.50 0.56
		No. 4 - US 24 - US 25 N from Vreeland Rd	BIT CONC BIT CONC BIT CONC BIT CONC	NBOL NBIL SBOL SBIL	0.56 0.59 0.55 0.56
15	River Road	On River Rd from approximately one mile W of Old US 31 (Buys Rd) W to Scenic Drive in Muskegon Co.	BIT CONC BIT CONC	EB WB	0.53 0.53
16	S 04 of 81063	Wiard Rd over EB US 12	CONC Sandblasted CONC Sandblasted CONC BIT BIT	NBOL NBCL NBIL NBCL (approach) NBCL (departure)	0.49 0.40 0.35 0.50 0.51
16	49031	M 117, N of Engadine	NSST Sandblasted NSST	NB SB	0.69 0.78

TABLE 27 (Cont.)
SPECIAL REQUEST TESTS

Special Request No.*	Project or Control Section Number	Location	Surface Type	Direction and Lane	Avg. Coefficient of Wet Sliding Friction
17	78061	M 86, between Centreville and M 66	Single Seal	EB	0.65
			Single Seal	WB	0.68
17	78061	300 ft maintenance patch located on M 86 approximately 1.5 mi. W of Nottawa	BIT	EB	0.26
			BIT	WB	0.27
17	78042	M 60 from Mendon W to Three Rivers	BC	EB	0.59
			BC	WB	0.60
--	41033	M 37, from I 96 N 1.5 mi. to the divided roadway	ST	NBOL	0.15
TR-1	Northline Rd	Northline Rd at Toledo Rd, Wayne County	BIT	NBOL	0.40
			BIT	NBCL	0.39
			BIT	NBIL	0.39
			BIT	SBOL	0.39
			BIT	SBCL	0.40
			BIT	SBIL	0.40
			Cont	EB	0.33
			BIT	WBOL	0.40
			BIT	WBIL	0.41
TR-1	West Rd	West Rd 0.25 mi. E of M 85 at the Penn Central RR overpass in Wayne County	BRICK	EBOL	0.48
			BRICK	EBIL	0.48
			BRICK	WBOL	0.42
			BRICK	WBIL	0.47
TR-2	Monroe Ave	Monroe Ave at Pearl St, Kent Co.	BRICK	EBOL	0.33
			BRICK	EBIL	0.36
			BRICK	WBOL	0.32
			BRICK	WBCL	0.37
			BRICK	WBLT	0.36
TR-2	Monroe Ave	Monroe Ave at Market Ave, Kent Co.	BRICK	EBOL	0.33
			BRICK	EBIL	0.36
			BRICK	WBOL	0.39
			BRICK	WBIL	0.36
TR-2	Monroe Ave	Monroe Ave at Ottawa Ave, Kent Co.	BRICK	EBOL	0.37
			BRICK	EBCL	0.35
			BRICK	EBIL	0.39
			BRICK	WBOL	0.40
			BRICK	WBIL	0.35
TR-2	Monroe Ave	Monroe Ave at Ionia Ave, Kent Co.	BRICK	EBOL	0.34
			BIT	EBOL	0.41
			BIT	NBRT	0.44
			BIT	NBCL	0.44
			BIT	NBIL	0.42
TR-2	Pearl St	Pearl St at Campau Ave, Kent Co.	BIT	EB	0.34
			BIT	WB	0.40
TR-2	41022	M 45 (Fulton St) at Sheldon Ave, Kent Co.	BIT	EBIL	0.40
			BIT	SBOL	0.41
			BIT	SBIL	0.37
TR-2	Ottawa Ave	Ottawa Ave at Michigan St, Kent Co.	BIT	SBRT	0.48
			BIT	SBOL	0.48
			BIT	SB#3	0.47
			BIT	SB#2	0.49
			BIT	SBIL	0.48

APPENDIX C

TEXTURED CONCRETE PAVEMENT SURFACES

F. Copple

Research Laboratory Section
Testing and Research Division
Research Project 70 F-114
Research Report No. R-756

Lansing, November 1970

TEXTURED CONCRETE PAVEMENT SURFACES

Introduction

This project was initiated to investigate different methods of texturing concrete pavement surfaces and to evaluate the performance of these textures with respect to skid resistance and noise.

Eisenhour Construction Co. agreed to apply certain textured finishes to a concrete pavement surface while constructing Project I 13074-001, a three mile length of I 69 beginning just north of I 94 in Calhoun County.

Sufficient wire combs were available to texture transversely, but not longitudinally; and enough nylon brushes to texture both transversely and diagonally. Longitudinal texturing requires a sufficient length of brushes or combs to span the full width of a 24-ft pavement, while transverse texturing requires lengths of only a few feet.

Construction

Continuous lengths of I 69 were specially textured in three ways:

1) transverse texture using nylon brushes,
2) transverse grooves using metal combs,
3) longitudinal texture using nylon brushes.

Total length of these special textures was about 4,600 ft of roadway (24 ft wide); the remainder of the pavement was finished with a conventional burlap drag. Table 1 gives the location of the special textured surface sites.

TABLE 1

LOCATION OF TEXTURED PAVEMENT SURFACE AREAS

Texture type	Limits, by station
Nylon brush (longitudinal)	2241+50 to 2249+88
Wire comb (transverse)	2249+88 to 2269+82
Nylon brush (transverse)	2270+53 to 2289+50

Brush, comb, and burlap finishes were each applied by mounting the appropriate texturing tools on the membrane curing application equipment at the project site. Figure 1 shows the nylon brushes mounted for longitudinal texturing.

Texturing presented no great problems during construction, and there was no trouble keeping pace with the CMI slip-form paver, used in casting the slab. The brushes, in common with a burlap drag, tended to collect a slurry as they textured. The wire combs always appeared clean with no indication of clogging or slurry retention.

Figures 2 through 4 show typical textures achieved on this project.

Performance

Skid resistance measurements were made about four months after the textured areas had been constructed. Initial skid test results, shown on Figure 5, give the ranges for three measurements made on each textured surface. All the surfaces exceed Michigan's minimum wet skid coefficient (measured at 40 mph) of 0.4. However, since stopping distance and traction on a wet pavement are directly related to skid coefficient, it is desirable that coefficients be as high as practicable. The transverse comb texture had the highest skid coefficient, the transverse nylon brush second highest, with the conventional burlap and longitudinal brush being lowest but still acceptable. It was noticed that the wheel tracks over part of the transverse comb textured pavement had been noticeably worn (Fig. 6).

A concrete batching plant was located adjacent to the test area and the textured surface roadway was used intensively by the contractor's trucks before the highway was opened for traffic. This traffic in combination with dirt on the pavement had caused the wear.

Wet skid coefficients measured in the worn wheel paths of the transverse comb texture are also shown in Figure 5. In such areas, skid coefficients had been reduced markedly to a level that was still acceptable, but still the lowest of the entire group. Because of the sharp shoulders on the grooves and the reduced mass available to resist wear, it seems likely that the transverse combed areas would always initially wear faster than brush or burlap treated areas. In transverse combed areas, initial skid resistance would probably decrease rapidly for a short time and then, after reaching a certain level, wear at the same rate as brush or burlap treated pavements.

It was also noted that vehicles traveling over wet transverse comb textured pavement did not generate the fog of water behind them that was apparent in other areas. This characteristic was especially apparent because of the large quantities of water thrown up behind trucks.

Noise level measurements were taken over the textured pavement by means of a microphone mounted near a tire on a trailer which was towed over the areas at three speeds: 15, 30, and 60 mph. There was a noticeable but not great difference in noise levels between the various textured surfaces. The transverse brushed area had a noise level slightly higher than that of the combed area and the longitudinal brush and burlap drag areas had equal noise levels which were lowest of the group. Noise generated by any of the textures was not considered to be great enough to be a factor in rejecting any of the texture types.

Discussion

A conventional burlap drag texture, when properly applied, provides acceptable skid resistance. However, burlap is subject to wind flap, can tend to create a wavy texture, and--if the concrete has set too long--does not score the surface as deeply as desired. On this, as with many other projects, areas of insufficient texturing exist where the concrete had set too long before burlaping. Wet skid coefficient tests (40 mph) for all new concrete pavements during 1969 ranged from 0.39 to 0.67. This shows how variable burlap texturing has proven to be. Therefore, burlap does present some job control problems. Neither nylon brushes or wire combs would be vulnerable to wind flap and, because of their rigid mounting, surface waves should be minimal. Although the depth of texturing would still depend upon the timing of the operation during the period of concrete set, it should not be as critical as the burlap drag since the burlap does not cut like bristles or comb teeth.

During this study, there was no realistic means of comparing costs for the different types of textures. However, it appears that brushes for longitudinal texturing could easily be mounted to replace the burlap drag on existing equipment and should justify no increased cost. Transverse texturing might require that a contractor purchase additional equipment. However, Indiana has required transverse texturing for years and any contractor who does work for the State would already own the necessary equipment. Therefore, since no additional operator or equipment time was required for transverse finishing, very little, if any additional cost can be expected.

Conclusions

1. Any of the textures used during this study, including burlap drag when properly applied, provide an acceptable skid resistant surface.

2. Job control of the degree of texture appears more difficult with the burlap drag than the other texturing methods.

3. Because of the fragile groove shoulders and the lesser mass of concrete on the wearing surface, the wire comb areas will wear more rapidly then the other types tested, consequently its initial very high skid resistance would be rapidly reduced.

4. The longitudinal brush texture was about equal to the burlap drag in initial skid resistance but apparently provided easier job control of texture than the burlap.

5. The transverse brush texture provided a desirable combination of high initial skid resistance and wear resistance which should approach that of a burlap drag finish.

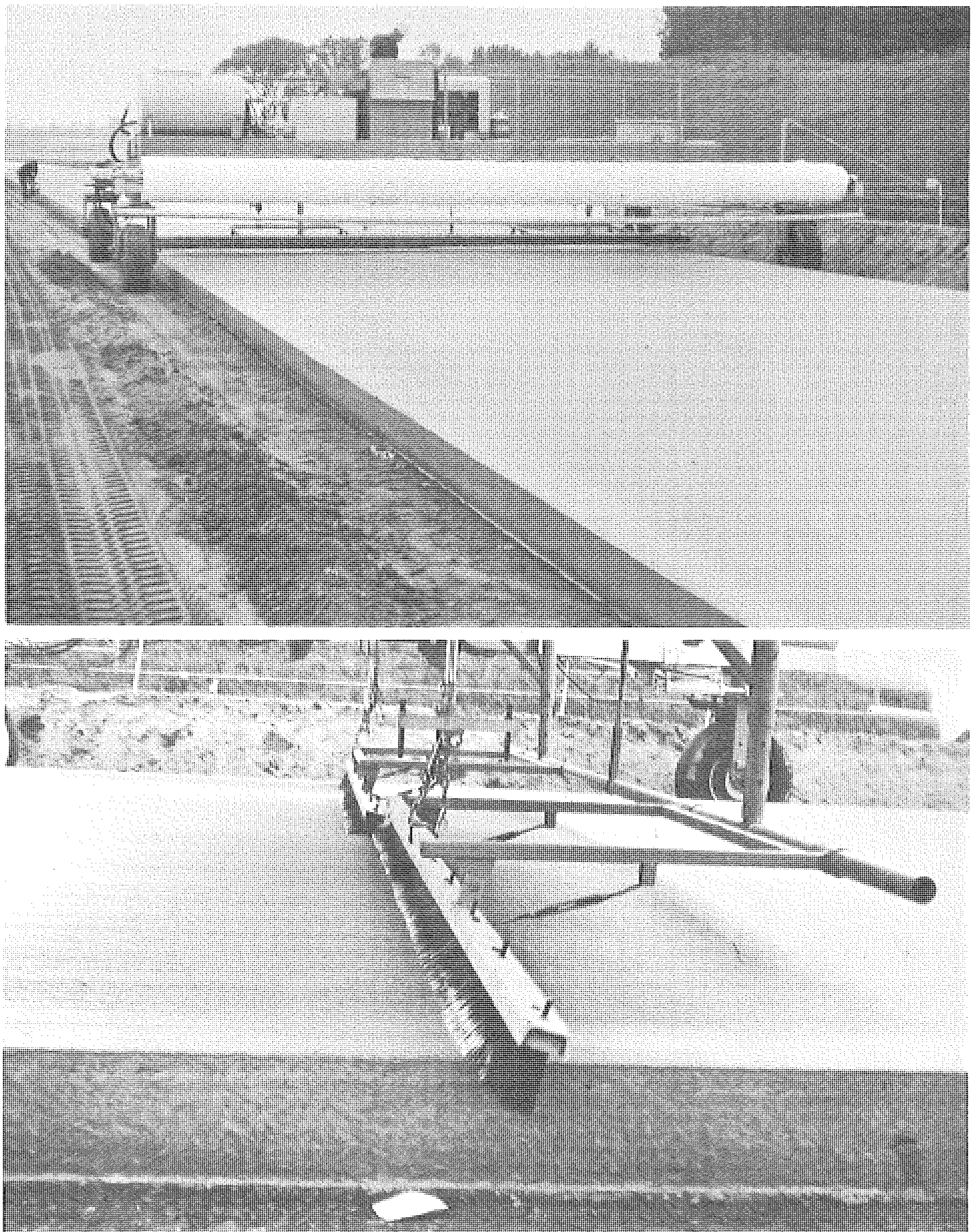


Figure 1. Longitudinal pavement texturing with nylon brushes.

Figure 2. Pavement textured with nylon brushes. Longitudinal texturing at left; transverse texturing at right.

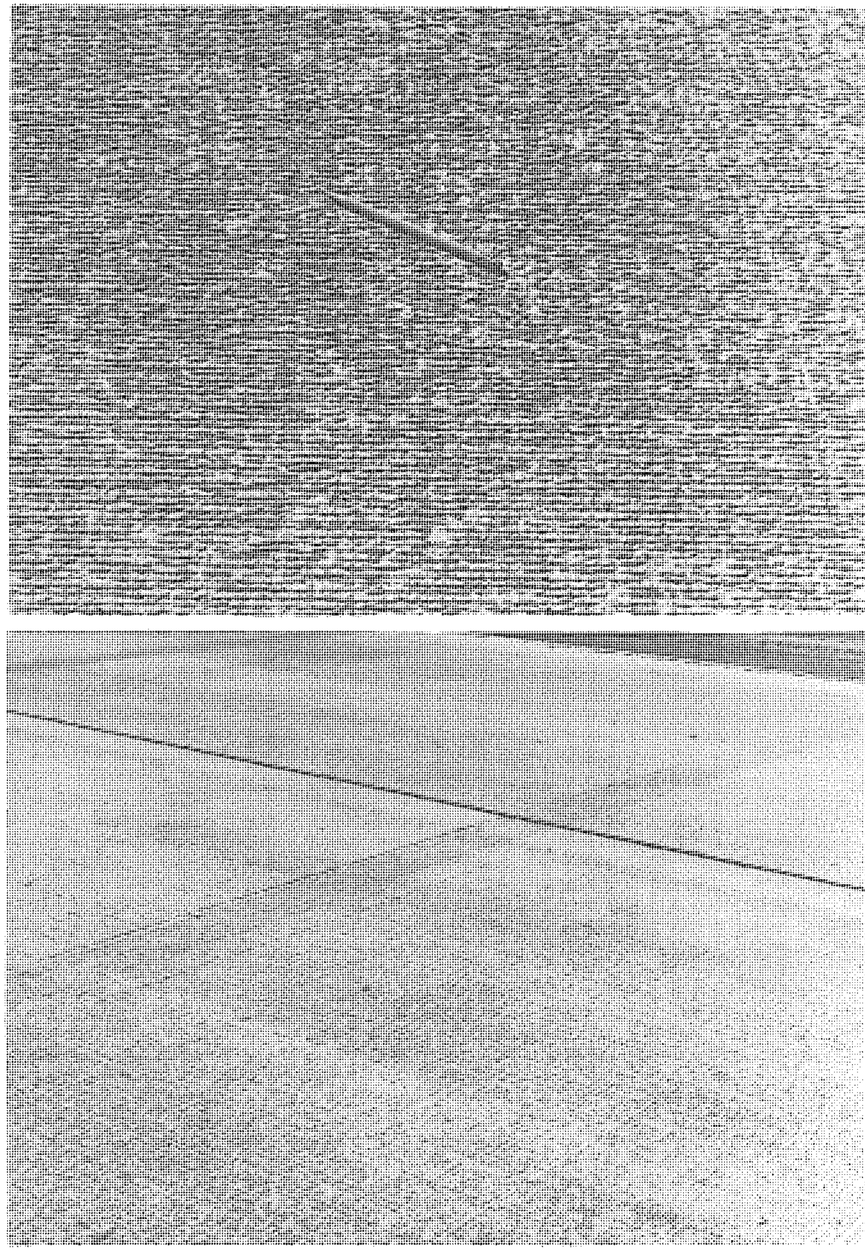
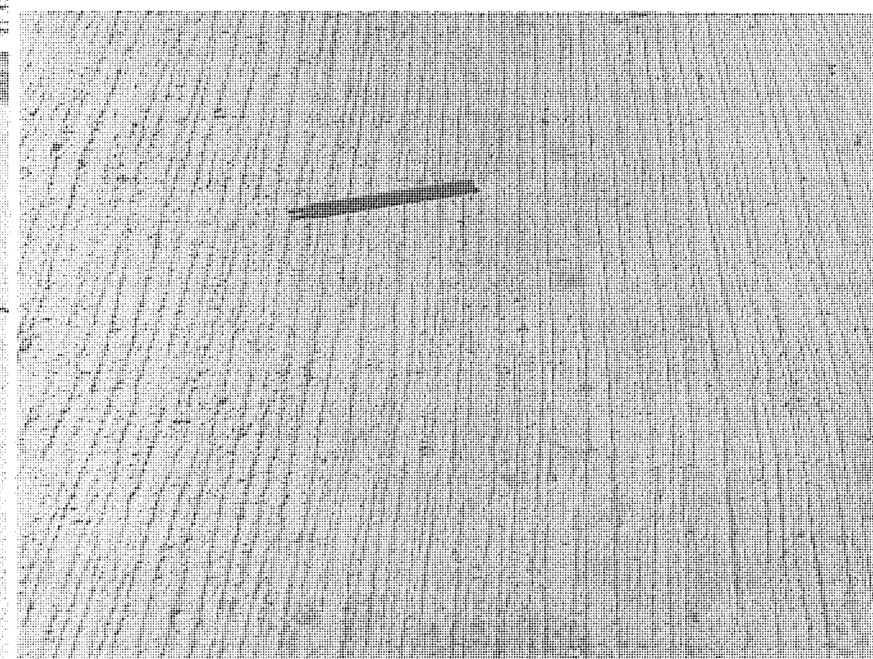


Figure 3. Transverse texturing with wire combs showing general view (lower left) and close-up.

Figure 4. Longitudinal burlap drag finish.



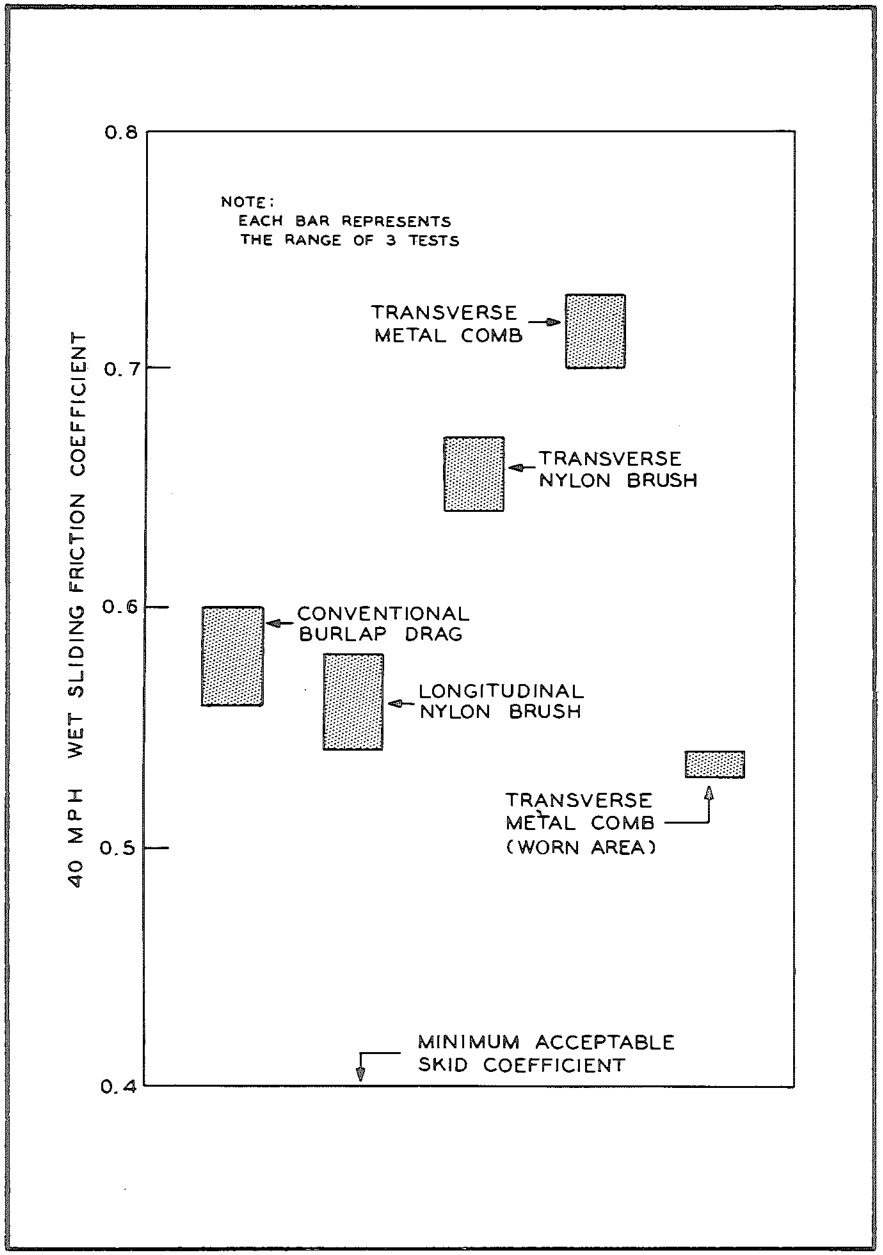
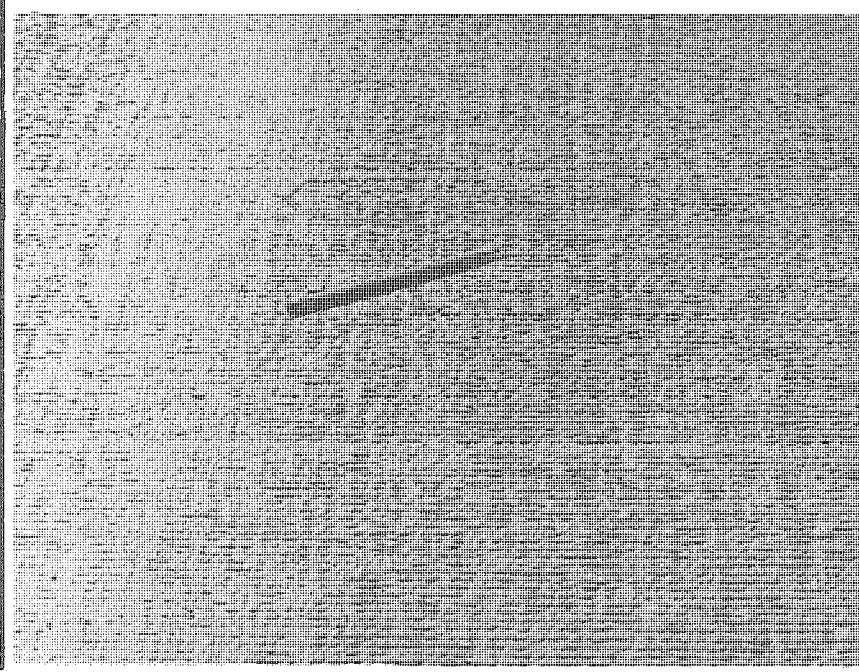


Figure 5. Initial skid coefficient for textured pavement surfaces. Construction Project I 13074-001.

Figure 6. Wheel path wear of wire comb texture (transverse).



APPENDIX D

SPECIFICATIONS FOR A PAVEMENT FRICTION TESTER

The Pavement Friction Tester shall be based on the General Motors Proving Ground Model 2 Coefficient of Friction Vehicle. The device consists of a truck-trailer combination designed to test skid and incipient friction resistance of pavements in accord with ASTM E 274-65T requirements (revised August 1969) and SAE J345. It will measure peak and locked wheel braking traction force for passenger car tires, and meet the proposed National Highway Safety Bureau testing standards.

The Tester shall consist of a modified 3/4-ton pickup truck, a 2-wheel trailer and all necessary equipment and instrumentation. It shall be capable of testing with either or both wheels locked at speeds up to 70 mph and be capable of making incipient (slip) friction measurements down to 2 mph during the lock-up cycle. It shall provide the following data:

1) Actual Wheel Friction Tractive Force at both test wheels
2) Dynamic Vertical Load Force at each wheel
3) Individual Angular Wheel Velocity
4) Percent Slip (scaled) During One Wheel Lock-Up
5) True Vehicle Speed
6) Distance Traveled in feet.

The trailer, the truck, and the electronic, pneumatic and hydraulic system shall be similar to the equipment described in SAE Publication 680137, "Tire-Road Friction Measuring System - A Second Generation," by G. L. Goodenow, T. R. Kolhoff, and F. D. Smithson of the General Motors Proving Grounds.

Truck

The truck shall be a late model Chevrolet 3/4-ton pickup truck with a 396 V-8 Chevrolet engine, compatible automatic transmission, "limited slip" differential, bucket seats, air conditioning, power steering and brakes, and suspension. Such truck shall be furnished by the Department and delivered to the Supplier of the Pavement Friction Tester for installation of equipment. The cab of the truck is to be modified to accommodate the electronic power supply, strip-chart recorder, and "systems control and electronics console."

Trailer

The two-wheel trailer is to be equipped with a coil spring suspension, stabilizer bar, hard bushings, and disc brakes. It shall be provided with the following accessories:

1. Model 1270 force transducers at both test wheels as described in this specification to provide direct measurement of the dynamic "horizontal tractive friction force" of pavement-tire braking traction, and the "dynamic vertical load" on the wheel during testing.

2. A fifth wheel with velocity and distance transducers mounted with a pneumatic pickup cylinder and automatic latch.

3. Angular velocity transducers mounted in each modified axle assembly of the trailer.

4. Laminar flow designed water nozzles for even distribution located ahead of each wheel and equipped with pneumatic cylinders to lower and raise the nozzles automatically for each test.

5. Hydraulic lift jacks for picking the trailer up for rapid tire changes.

6. An air wrench with a 25-ft coil-type flexible line to operate from a quick-disconnect fitting on the trailer tongue for wheel changes.

7. Hydraulic Cylinder and Tension Load Cell assembly for calibration of the force transducers. M1275 Air Bearing Calibration Platform included.

8. Provision for varying axle loads from 800 lb minimum to 1,600 lb maximum.

9. Trailer cover constructed of a molded, one-piece, fiberglass shell.

10. Rear of the trailer cover is to be fitted with a bumper and tail, brake, turn-signal, and backup lights. Four red safety lights, flashing in pairs alternately, are located at the top rear of the trailer body for use while the test is in progress.

11. Locators by which to determine trailer position during backup procedure.

12. Provision to use 14-in. wheel size.

13. Two spare wheels with ASTM test tires mounted.

Brakes

The trailer brakes shall be capable of locking the left, the right, or both wheels in a lock-up time from hydraulic pressure application to 10 percent slip of 0.5 seconds to 30 seconds when measuring either wet or dry skid resistance. The trailer brakes will also be operable when the truck brakes are applied.

Watering System

The system shall consist of a 230 gal baffled tank located in the front portion of the truck bed, two individually operated positive displacement water pumps, valves, and water laying nozzles. Dual flexible hoses shall route the water to the distributing valving on the trailer. The system is automatically to deliver 3.6 gal/min/in. of wetted width evenly distributed water layer at operating speeds of 20 to 70 mph to the wheel or wheels being locked for skidding in accord with ASTM E 274-65T (rev. August 1969).

Transducers

1. Force transducers for each wheel shall have strain gage bridges and shall have less than 2 percent of applied load nonlinearity and hysteresis errors. When subjected to torsional load only they shall have less than 2 percent of applied force load crosstalk under 500 ft-lb load in the torque mode.

2. The velocity transducers shall have less than 2 percent nonlinearity between 20 and 70 mph.

Electronics

Accuracy of all signal conditioning circuitry shall be within ± 2 percent using simulated input in an air-conditioned environment.

Recorder

The recorder shall be a Brush Oscillograph Model 16-2308-00, or equivalent conforming to the manufacturer's specifications, including six galvanometers. Such recorder shall be furnished by the Department and delivered to the Supplier for installation in the Pavement Friction Tester.

The Pavement Friction Tester shall conform to or exceed the requirements of ASTM E 274-65T, "Tentative Standard Specifications for A Method of Testing for Skid Resistance of Pavement Using a Trailer," as revised in August, 1969 for final adoption. This specification is cited for use to meet the National Highway Safety Bureau Test Requirements.

Any improvements or modifications in the design of the Friction Tester may be incorporated prior to assembly, but only upon approval and authorization of the purchaser.

Complete description of the Pavement Friction Tester, including all system drawings, shall be provided with the operating and maintenance instructions at the time of delivery of the Tester.

Delivery of the Tester will be accepted at the home-site of the Supplier at which time final inspection of all components will be made and the operability of all systems will be determined. Adequate time will be allocated by the Supplier to instruct the assigned operating personnel in the operation and calibration of the Tester, as well as in the care and maintenance procedure of its vital components. Such instruction will be provided at no extra charge to the Department.

APPENDIX E

A SURVEY OF VEHICLES USING STUDDED, SMOOTH, OR SNOW TIRES IN MICHIGAN

F. Copple

Research Laboratory Section
Testing and Research Division
Research Project 69 G-173
Research Report No. R-775

Lansing, July 1971

Researchers studying pavement friction are aware that the ASTM Standard Pavement Test Tire does not have characteristics identical to conventional automobile tires. However, no one tire could precisely represent the wide variety of tires rolling over Michigan highways. The millions of vehicles using Michigan highways travel on tires of various tread designs, materials, structural types, and states of wear. In order to obtain data so that we might intelligently apply skid test measurements, it was believed that we should learn something of the variation among tires now in use. Therefore, it was decided to conduct a statewide survey of vehicle tire use with tires categorized as: 1) smooth tires (tires with 2/32 in. or less of tread remaining), 2) studded tires, and 3) snow tires.

A survey of vehicles using studded tires had been made by the Research Laboratory during winter 1969-70. Samples for that survey were proportionally allocated, based upon county vehicle registration data. Data from that survey were used to develop a more efficient sampling plan, described in Appendix A, for use in winter 1970-71. Although the plan was developed primarily as a means of estimating tire stud use, it was also used to estimate proportions of vehicles with smooth tires and with snow tires. The sample consisted of 27,025 vehicles, allocated by counties as listed in Table 1. The survey began on January 11, 1971 and extended through February 19.

Only vehicles with Michigan license plates were counted in the survey; State-owned vehicles were not counted nor were trucks other than pickup and panel trucks. After selecting a site, a "cluster" containing a predetermined number of vehicles was surveyed in the order of their physical location. That is, once the cluster was selected, there was no choosing among vehicles, they were inspected in order. Sites were primarily parking lots, but in smaller towns vehicles parked on streets were surveyed.

Table 1 is an alphabetical listing of counties showing numbers of vehicles surveyed, proportions of vehicles with studs, and axle location of studded tires. Table 2 gives the same information but is separated by District, Table 3 relates studded tire use to type of vehicle, and Table 4 lists counties in decreasing order of studded tire use. Figure 1 is a map of the State showing tire stud use by counties. Table 5 compares tire stud survey results for this year and last, Table 6 lists the precision of the estimated proportion for each county.

Tables 7 and 8 show data for snow tires and for smooth tires. Since 1971 was the first year for surveying snow tires and smooth tires, no past year comparisons are available. Tire studs are permitted on vehicles in Michigan from November 1 to May 1 and snow tires are generally used only during those months, thus the results of this survey are valid for the same period.

The Statewide average proportion of vehicles using studded tires increased from about 12 percent in 1969-70 to 15.2 percent in 1970-71. More significantly perhaps, is the fact that the number of vehicles having tire studs in 1970-71 increased over 27 percent. The precision of this estimated proportion is within a fraction of 1 percent, at the 95 percent confidence level.

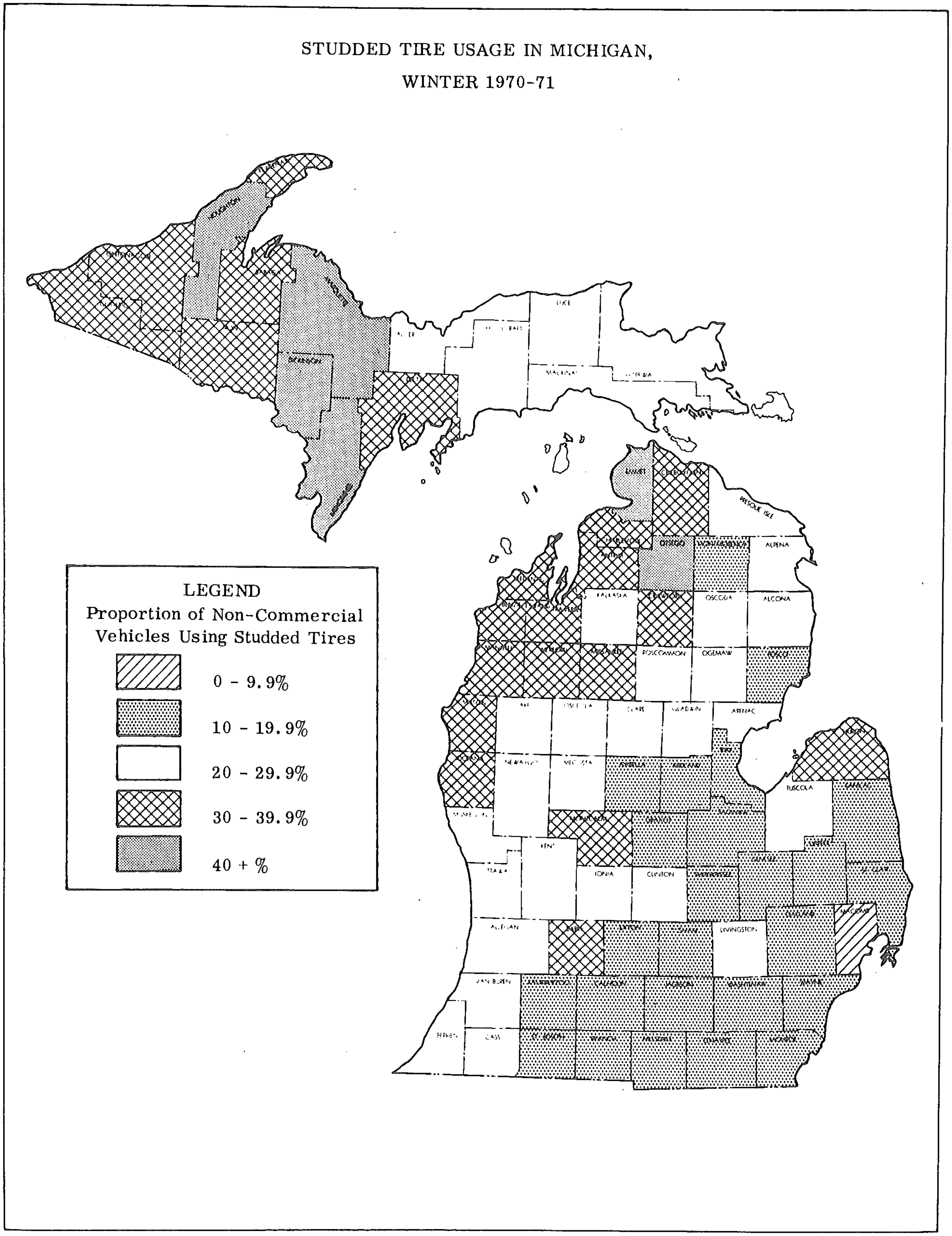


Figure 1. Studded tire usage in Michigan, winter 1970-1971.

TABLE 1
WINTER, 1970-1971 STUDDED TIRE SURVEY BY COUNTIES

County	No. of Vehicles	Percent of Vehicles			
		Without Studs	With Studs on Front Only	With Studs on Rear Only	With Studs on Front and Rear
Alcona	100	72.00	0	28.00	0
Alger	125	73.60	0	26.40	0
Allegan	400	73.00	0	27.00	0
Alpena	200	76.00	0	23.50	0.5
Antrim	100	68.00	0	31.00	1
Arenac	100	73.00	0	27.00	0
Baraga	100	69.00	0	30.00	1
Barry	200	63.50	0	36.00	0.5
Bay	700	83.70	0	16.30	0
Benzie	100	62.00	0	37.00	1
Berrien	1000	78.60	0	21.40	0
Branch	200	88.00	0	12.00	0
Calhoun	800	87.75	0	12.25	0
Cass	100	76.00	0	24.00	0
Charlevoix	100	69.00	0	31.00	0
Cheboygan	100	64.00	0	36.00	0
Chippewa	200	71.50	0	28.50	0
Clare	100	79.00	0	21.00	0
Clinton	200	78.00	0	22.00	0
Crawford	100	65.00	0	35.00	0
Delta	200	68.00	0	31.50	0.5
Dickinson	100	51.00	0	49.00	0
Eaton	300	89.70	0	10.30	0
Emmet	100	60.00	0	40.00	0
Genesee	800	82.875	0	17.125	0
Gladwin	100	73.00	0	27.00	0
Gogebic	100	65.00	0	35.00	0
Grand Traverse	200	65.50	0	34.50	0
Gratiot	200	85.00	0	15.00	0
Hillsdale	200	83.00	0	17.00	0
Houghton	200	54.50	0	45.50	0
Huron	200	68.00	0	32.00	0
Ingham	1200	86.70	0	13.30	0
Ionia	200	79.00	0	21.00	0
Iosco	100	81.00	0	19.00	0
Iron	100	68.00	0	32.00	0
Isabella	200	83.00	0	17.00	0
Jackson	600	80.20	0	19.80	0
Kalamazoo	1100	85.10	0	14.90	0
Kalkaska	100	73.00	0	27.00	0
Kent	1500	78.90	0	21.00	0.1
Keweenaw	100	63.00	0	37.00	0
Lake	100	80.00	0	20.00	0
Lapeer	200	87.00	0	13.00	0
Leelanau	100	62.00	0	37.00	1

TABLE 1 (Cont.)

WINTER, 1970-1971 STUDDED TIRE SURVEY BY COUNTIES

County	No. of Vehicles	Percent of Vehicles			
		Without Studs	With Studs on Front Only	With Studs on Rear Only	With Studs on Front and Rear
Lenawee	500	85.80	0	14.20	0
Livingston	300	79.30	0.7	20.00	0
Luce	100	73.00	0	27.00	0
Mackinac	100	73.00	0	27.00	0
Macomb	1000	92.30	0	7.70	0
Manistee	100	65.00	0	34.00	1
Marquette	300	58.40	0.3	41.30	0
Mason	100	67.00	0	33.00	0
Mecosta	100	75.00	0	25.00	0
Menominee	100	59.00	0	41.00	0
Midland	400	78.25	0	21.50	0.25
Missaukee	100	65.00	0	35.00	0
Monroe	600	85.70	0	14.10	0.2
Montcalm	200	68.50	0	31.50	0
Montmorency	100	84.00	0	16.00	0
Muskegon	900	75.60	0	25.20	0.2
Newaygo	200	74.00	0	26.00	0
Oakland	1200	87.9	0.1	11.90	0.1
Oceana	100	64.00	1	35.00	0
Ogemaw	100	76.00	0	23.00	1
Ontonagon	100	65.00	0	35.00	0
Osceola	100	75.00	0	25.00	0
Oscoda	100	75.00	0	25.00	0
Otsego	100	56.00	0	44.00	0
Ottawa	700	75.40	0	24.60	0
Presque Isle	100	73.00	0	27.00	0
Roscommon	100	79.00	0	21.00	0
Saginaw	900	85.90	0	14.10	0
Sanilac	200	89.00	0	11.00	0
Schoolcraft	100	74.00	0	26.00	0
Shiawassee	300	85.70	0	14.30	0
St. Clair	700	89.60	0	10.40	0
St. Joseph	300	86.30	0	13.70	0
Tuscola	200	77.50	0	22.50	0
Van Buren	300	75.30	0	24.70	0
Washtenaw	1200	88.25	0	11.75	0
Wayne	1500	90.00	0	10.00	0
Wexford	100	66.00	0	33.00	1

TABLE 2
WINTER, 1970-1971 STUDDED TIRE SURVEY BY DISTRICTS

District	No. of Vehicles	Percent of Vehicles			
		Without Studs	With Studs on Front Only	With Studs on Rear Only	With Studs on Front and Rear
1	1200	60.42	0.08	39.42	0.08
2	825	71.64	0.00	28.24	0.12
3	1400	68.60	0.00	31.00	0.40
4	1300	72.08	0.00	27.77	0.15
5	4500	78.40	0.02	21.50	0.08
6	4100	82.44	0.00	17.54	0.02
7	4400	81.34	0.00	18.64	0.02
8	4300	85.62	0.05	14.33	0.00
9	2900	89.21	0.03	10.73	0.03
10	2100	88.76	0.00	11.19	0.05
Total	27025	80.60	0.02	19.32	0.06

TABLE 3
WINTER, 1970-1971 STUDDED TIRE SURVEY BY VEHICLE TYPES

Vehicle		Percent of Vehicles			
Type	No.	None	Front	Rear	Front and Rear
Passenger car	25767	80.5	0.0	19.5	0.0
Pickup & panel trucks	1082	81.7	0.0	18.3	0.0
4 wheel drive	176	87.5	0.0	4.5	8.0

TABLE 4
PERCENT OF VEHICLES USING STUDDED TIRES BY COUNTIES

County	Percent	County	Percent	County	Percent
Dickinson	49.00	Alcona	28.00	Livingston	20.70
Houghton	45.50	Allegan	27.00	Lake	20.00
Otsego	44.00	Arenac	27.00	Jackson	19.80
Marquette	41.67	Gladwin	27.00	Iosco	19.00
Menominee	41.00	Kalkaska	27.00	Genesee	17.13
Emmet	40.00	Luce	27.00	Hillsdale	17.00
Benzie	38.00	Mackinac	27.00	Isabella	17.00
Leelanau	38.00	Presque Isle	27.00	Bay	16.30
Keweenaw	37.00	Alger	26.40	Montmorency	16.00
Barry	36.50	Newaygo	26.00	Gratiot	15.00
Cheboygan	36.00	Schoolcraft	26.00	Kalamazoo	14.90
Oceana	36.00	Muskegon	25.40	Monroe	14.30
Crawford	35.00	Mecosta	25.00	Shiawassee	14.30
Gogebic	35.00	Osceola	25.00	Lenawee	14.20
Manistee	35.00	Oscoda	25.00	Saginaw	14.10
Missaukee	35.00	Van Buren	24.70	St. Joseph	13.70
Ontonagon	35.00	Ottawa	24.60	Ingham	13.30
Grand Traverse	34.50	Alpena	24.00	Lapeer	13.00
Wexford	34.00	Cass	24.00	Calhoun	12.25
Mason	33.00	Ogemaw	24.00	Oakland	12.10
Antrim	32.00	Tuscola	22.50	Branch	12.00
Delta	32.00	Clinton	22.00	Washtenaw	11.75
Huron	32.00	Midland	21.75	Sanilac	11.00
Iron	32.00	Berrien	21.40	St. Clair	10.40
Montcalm	31.50	Kent	21.10	Eaton	10.30
Baraga	31.00	Clare	21.00	Wayne	10.00
Charlevoix	31.00	Ionia	21.00	Macomb	7.70
Chippewa	28.50	Roscommon	21.00		

TABLE 5
COMPARISON OF 1969-1970 AND 1970-1971 SURVEYS

County	Registered Vehicles	1969-1970 Vehicles With Studded Tires	1969-1970 Studded Tire Proportion	1970-1971 Vehicles With Studded Tires	1970-1971 Studded Tire Proportion
Alcona	3886	427.46	0.11	1088.08	0.28
Alger	3270	981.00	0.30	863.28	0.26
Allegan	27901	4812.92	0.17	7533.27	0.27
Alpena	13432	1007.40	0.08	3223.68	0.24
Antrim	5168	1292.00	0.25	1653.76	0.32
Arenac	4467	625.38	0.14	1206.09	0.27
Baraga	3231	969.30	0.30	1001.61	0.31
Barry	14301	3289.23	0.23	5219.87	0.37
Bay	50619	4120.39	0.08	8250.90	0.16
Benzie	3830	880.90	0.23	1455.40	0.38
Berrien	78346	9793.25	0.13	16766.04	0.21
Branch	15912	1352.52	0.09	1909.44	0.12
Calhoun	65290	6692.23	0.10	7998.03	0.12
Cass	19065	2478.45	0.13	4575.60	0.24
Charlevoix	6974	1255.32	0.18	2161.94	0.31
Cheboygan	6931	1594.13	0.23	2495.16	0.36
Chippewa	11691	1870.56	0.16	3331.94	0.29
Clare	6722	1344.40	0.20	1411.62	0.21
Clinton	16667	1583.37	0.10	3666.74	0.22
Crawford	2911	727.75	0.25	1018.85	0.35
Delta	14653	3003.87	0.21	4688.96	0.32
Dickinson	10815	2595.60	0.24	5299.35	0.49
Eaton	27415	2193.20	0.08	2823.75	0.10
Emmet	8261	2726.13	0.33	3304.40	0.40
Genesee	195742	17244.87	0.09	33520.82	0.17
Gladwin	5249	577.39	0.11	1417.23	0.27
Gogebic	8575	1457.75	0.17	3001.25	0.35
Grand Traverse	19371	4261.62	0.22	6683.00	0.35
Gratiot	16784	2601.52	0.16	2517.60	0.15
Hillsdale	16209	1458.81	0.09	2755.53	0.17
Houghton	12659	5316.78	0.42	5759.85	0.46
Huron	15225	2816.63	0.19	4872.00	0.32
Ingham	115471	14780.29	0.13	15357.64	0.13
Ionia	18462	3323.16	0.18	3877.02	0.21
Iosco	9432	660.24	0.07	1792.08	0.19
Iron	6118	734.16	0.12	1957.76	0.32
Isabella	13974	2165.97	0.16	2375.58	0.17
Jackson	62310	4050.15	0.07	12337.38	0.20
Kalamazoo	86705	15684.93	0.18	12919.04	0.15
Kalkaska	2411	530.42	0.22	650.97	0.27
Kent	185857	33212.65	0.18	39215.83	0.21
Keweenaw	837	292.95	0.35	309.69	0.37
Lake	2254	225.40	0.10	450.80	0.20
Lapeer	19530	1269.45	0.07	2538.90	0.13
Leelanau	4460	758.20	0.17	1694.80	0.38

TABLE 5 (Cont.)
COMPARISON OF 1969-1970 AND 1970-1971 SURVEYS

County	Registered Vehicles	1969-1970 Vehicles With Studded Tires	1969-1970 Studded Tire Proportion	1970-1971 Vehicles With Studded Tires	1970-1971 Studded Tire Proportion
Lenawee	36526	1826.30	0.05	5186.69	0.14
Livingston	22829	3349.01	0.15	4725.60	0.21
Luce	2374	688.46	0.29	640.98	0.27
Mackinac	3525	634.50	0.18	951.75	0.27
Macomb	282989	25469.01	0.09	21790.15	0.08
Manistee	8950	2148.00	0.24	3132.50	0.35
Marquette	24144	9730.03	0.40	10060.08	0.42
Mason	9652	1833.88	0.19	3185.16	0.33
Mecosta	9995	1599.20	0.16	2498.75	0.25
Menominee	10607	954.63	0.09	4348.87	0.41
Midland	29150	4372.50	0.15	6340.13	0.22
Missaukee	2795	698.75	0.25	978.25	0.35
Monroe	50784	3133.37	0.06	7262.11	0.14
Montcalm	17672	2120.64	0.12	5566.68	0.32
Montmorency	2418	241.80	0.10	386.88	0.16
Muskegon	68258	12511.69	0.18	17337.53	0.25
Newaygo	12423	3167.87	0.26	3229.98	0.26
Oakland	432637	47979.44	0.11	52349.08	0.12
Oceana	6638	1659.50	0.25	2389.68	0.36
Ogemaw	5116	869.72	0.17	1227.84	0.24
Ontonagon	4174	500.88	0.12	1460.90	0.35
Osceola	6262	1252.40	0.20	1565.50	0.25
Oscoda	2030	263.90	0.13	507.50	0.25
Otsego	4562	821.16	0.18	2007.28	0.44
Ottawa	55505	10623.66	0.19	13654.23	0.25
Presque Isle	5149	463.41	0.09	1390.23	0.27
Roscommon	5298	1006.62	0.19	1112.58	0.21
Saginaw	92725	8039.26	0.09	13074.22	0.14
Sanilac	14304	2002.56	0.14	1573.44	0.11
Schoolcraft	3619	1085.70	0.30	940.94	0.26
Shiawassee	26421	3521.92	0.13	3778.20	0.14
St. Clair	50958	4076.64	0.08	5299.63	0.10
St. Joseph	22152	2215.20	0.10	3034.82	0.14
Tuscola	19292	4147.78	0.22	4340.70	0.23
Van Buren	24204	3872.64	0.16	5978.39	0.25
Washtenaw	97229	10131.26	0.10	11424.41	0.12
Wayne	1178938	114239.10	0.10	117893.80	0.10
Wexford	9101	2184.24	0.24	3094.34	0.34

Weighted 1969-70 Statewide Tire Stud Proportion = 0.1195849
Weighted 1970-71 Statewide Tire Stud Proportion = 0.1524489

Increase in percent of cars having studded tires since 1969-70 = 3.2864 %.

TABLE 6
SUMMARY OF 1970-1971 STUDDED TIRE SURVEY DATA

County	Vehicle Registration	Number of Clusters in County	Number of Clusters Sampled	Vehicles per Cluster	Number of Vehicles With Studs	Proportion With Studs	Standard Deviation	Precision of Estimated Proportion With Studs (95% Confidence)
Alcona	3886	155.44	4	25	28	.28	.03	.03
Alger	3270	130.80	5	25	33	.264	.03	.03
Allegan	27901	558.02	8	50	108	.27	.02	.01
Alpena	13432	537.28	8	25	48	.24	.04	.03
Antrim	5168	206.72	4	25	32	.32	.03	.03
Arenac	4467	178.68	4	25	27	.27	.05	.05
Baraga	3231	129.24	4	25	31	.31	.02	.02
Barry	14301	572.04	8	25	73	.36	.03	.02
Bay	50619	1012.38	14	50	114	.16	.02	.01
Benzie	3830	153.20	4	25	38	.38	.06	.06
Berrien	78346	783.46	10	100	214	.214	.02	.01
Branch	15912	636.48	8	25	24	.12	.02	.01
Calhoun	65290	652.90	8	100	98	.12	.01	.01
Cass	19065	762.60	4	25	24	.24	.05	.05
Charlevoix	6974	278.96	4	25	31	.31	.02	.02
Cheboygan	6931	277.24	4	25	36	.36	.03	.03
Chippewa	11691	467.64	8	25	57	.28	.04	.03
Clare	6722	268.88	4	25	21	.21	.02	.02
Clinton	16667	666.68	8	25	44	.22	.03	.02
Crawford	2911	116.44	4	25	35	.35	.06	.06
Delta	14653	586.12	8	25	63	.315	.05	.03
Dickinson	10815	432.60	4	25	49	.49	.03	.03
Eaton	27415	1096.60	12	25	31	.10	.01	.01
Emmet	8261	330.44	4	25	40	.40	.03	.03
Genesee	195742	1957.42	8	100	137	.17	.02	.01
Gladwin	5249	209.96	4	25	27	.27	.03	.03
Gogebic	8575	343.00	4	25	35	.35	.04	.04
Grand Traverse	19371	774.84	8	25	69	.35	.03	.02
Gratiot	16784	671.36	8	25	30	.15	.03	.02
Hillsdale	16209	648.36	8	25	34	.17	.02	.01
Houghton	12659	506.36	8	25	91	.46	.07	.05
Huron	15225	609.00	8	25	64	.37	.05	.03
Ingham	115471	1154.71	12	100	160	.13	.01	.01
Ionia	18462	738.48	8	25	42	.21	.03	.02
Iosco	9432	377.28	4	25	19	.19	.03	.03
Iron	6118	244.72	4	25	32	.32	.02	.02
Isabella	13974	558.96	8	25	34	.17	.03	.02
Jackson	62310	1246.20	12	50	119	.20	.03	.02
Kalamazoo	86705	867.05	11	100	164	.15	.03	.02
Kalkaska	2411	96.44	4	25	27	.27	.03	.03
Kent	185857	1858.57	15	100	316	.21	.01	.01
Keweenaw	837	33.48	4	25	37	.37	.02	.02

TABLE 6 (Cont.)
SUMMARY OF 1970-1971 STUDDED TIRE SURVEY DATA

County	Vehicle Registration	Number of Clusters in County	Number of Clusters Sampled	Vehicles per Cluster	Number of Vehicles With Studs	Proportion With Studs	Standard Deviation	Precision of Estimated Proportion With Studs (95% Confidence)
Lake	2254	90.16	4	25	20	.20	.04	.04
Lapeer	19530	781.20	8	25	26	.13	.03	.02
Leelanau	4460	178.40	4	25	38	.38	.08	.08
Lenawee	36526	730.52	10	50	71	.14	.02	.01
Livingston	22829	913.16	12	25	62	.21	.03	.02
Luce	2374	94.96	4	25	27	.27	.03	.03
Mackinac	3525	141.00	4	25	27	.27	.06	.06
Macomb	282989	2829.89	10	100	77	.08	.01	.01
Manistee	8950	358.00	4	25	35	.35	.05	.05
Marquette	24144	965.76	12	25	125	.42	.04	.02
Mason	9652	386.08	4	25	33	.33	.01	.01
Mecosta	9995	399.80	4	25	25	.25	.06	.06
Menominee	10607	424.28	4	25	41	.41	.07	.07
Midland	29150	583.00	8	50	87	.22	.02	.01
Missaukee	2795	111.80	4	25	35	.35	.04	.04
Monroe	50784	1015.68	12	50	86	.14	.02	.01
Montcalm	17672	706.88	8	25	63	.32	.03	.02
Montmorency	2418	96.72	4	25	16	.16	.04	.04
Muskegon	68258	1365.16	18	50	229	.25	.02	.01
Newaygo	12423	496.92	8	25	52	.26	.02	.01
Oakland	432637	4326.37	12	100	145	.12	.02	.01
Oceana	6638	265.52	4	25	36	.36	.09	.09
Ogemaw	5116	204.64	4	25	24	.24	.04	.04
Ontonagon	4174	166.96	4	25	35	.35	.04	.04
Osceola	6262	250.48	4	25	25	.25	.06	.06
Oscoda	2030	81.20	4	25	25	.25	.05	.05
Otsego	4562	182.48	4	25	44	.44	.04	.04
Ottawa	55505	1110.10	14	50	172	.25	.02	.01
Presque Isle	5149	205.96	4	25	27	.27	.05	.05
Roscommon	5298	211.92	4	25	21	.21	.01	.01
Saginaw	92725	927.25	9	100	127	.24	.02	.01
Sanilac	14304	572.16	8	25	22	.11	.02	.01
Schoolcraft	3619	144.76	4	25	26	.26	.04	.04
Shiawassee	26421	1056.84	12	25	43	.14	.02	.01
St. Clair	50958	1019.16	14	50	73	.10	.01	.01
St. Joseph	22152	886.08	12	25	41	.14	.02	.01
Tuscola	19292	771.68	8	25	45	.23	.04	.03
Van Buren	24204	968.16	12	25	74	.25	.03	.02
Washtenaw	97229	972.29	12	100	141	.12	.02	.01
Wayne	1178938	11789.38	15	100	150	.10	.01	.01
Wexford	9101	364.04	4	25	34	.34	.02	.02

TABLE 7
RESULTS, BY COUNTIES, OF 1971 TIRE SURVEY

County	Vehicle Tire Condition, percent				
	One Smooth	Two Smooth	Three Smooth	All Smooth	None Smooth
Alcona	1.00	10.00	0.00	2.00	87.00
Alger	4.80	8.80	1.60	2.40	82.40
Allegan	5.50	13.00	0.50	0.75	80.25
Alpena	6.00	7.00	0.50	0.50	86.00
Antrim	4.00	10.00	0.00	4.00	82.00
Arenac	6.00	17.00	1.00	2.00	74.00
Baraga	5.00	4.00	0.00	0.00	91.00
Barry	5.50	11.00	1.50	4.00	78.00
Bay	4.86	9.00	1.00	2.57	82.57
Benzie	3.00	6.00	2.00	1.00	88.00
Berrien	2.80	13.20	0.90	4.20	78.90
Branch	5.50	7.00	1.50	4.50	81.50
Calhoun	6.25	7.13	1.50	4.50	79.37
Cass	2.00	11.00	0.00	2.00	85.00
Charlevoix	4.00	11.00	1.00	5.00	79.00
Cheboygan	0.00	13.00	0.00	0.00	87.00
Chippewa	4.00	4.00	0.00	0.00	92.00
Clare	1.00	11.00	1.00	5.00	82.00
Clinton	3.50	2.00	0.00	1.50	93.00
Crawford	3.00	16.00	0.00	5.00	76.00
Delta	5.50	7.00	0.50	0.00	87.00
Dickinson	5.00	3.00	2.00	0.00	90.00
Eaton	3.67	2.67	0.33	0.33	93.00
Emmet	3.00	11.00	0.00	1.00	85.00
Genesee	5.00	8.88	0.87	2.25	83.00
Gladwin	9.00	12.00	0.00	2.00	77.00
Gogebic	0.00	3.00	0.00	0.00	97.00
Grand Traverse	2.00	3.00	0.50	0.50	94.00
Gratiot	3.50	10.50	1.50	3.50	81.00
Hillsdale	3.00	4.00	0.50	0.00	92.50
Houghton	5.50	3.00	0.00	0.00	91.50
Huron	7.50	16.50	0.50	3.50	72.00
Ingham	3.92	2.33	0.08	0.08	93.59
Ionia	5.50	14.00	1.50	3.00	76.00
Iosco	4.00	13.00	0.00	1.00	82.00
Iron	4.00	2.00	0.00	0.00	94.00
Isabella	3.00	17.50	1.50	1.50	76.50
Jackson	3.67	3.83	0.33	0.83	91.84
Kalamazoo	4.46	12.08	0.63	3.27	79.56
Kalkaska	2.00	13.00	2.00	5.00	78.00
Kent	6.33	10.47	0.93	2.00	80.27
Keweenaw	3.00	2.00	0.00	0.00	95.00

TABLE 7 (Cont.)
RESULTS, BY COUNTIES, OF 1971 TIRE SURVEY

County	Vehicle Tire Condition, percent				
	One Smooth	Two Smooth	Three Smooth	All Smooth	None Smooth
Lake	2.00	3.00	0.00	0.00	95.00
Lapeer	6.00	7.00	1.00	5.00	81.00
Leelanau	6.00	4.00	1.00	0.00	89.00
Lenawee	3.20	2.20	0.00	0.40	94.20
Livingston	5.00	4.33	0.67	0.00	90.00
Luce	2.00	1.00	1.00	0.00	96.00
Mackinaw	3.00	4.00	0.00	0.00	93.00
Macomb	2.90	8.40	0.50	2.00	86.20
Manistee	4.00	5.00	0.00	1.00	90.00
Marquette	3.33	4.00	0.00	0.00	92.67
Mason	4.00	7.00	0.00	1.00	88.00
Mecosta	4.00	5.00	0.00	0.00	91.00
Menominee	4.00	7.00	1.00	1.00	87.00
Midland	3.00	11.25	0.75	0.75	84.25
Missaukee	3.00	13.00	2.00	2.00	80.00
Monroe	5.00	4.50	0.33	0.17	90.00
Montcalm	0.50	4.00	0.00	0.00	95.50
Montmorency	1.00	11.00	0.00	0.00	88.00
Muskegon	1.56	1.33	0.11	0.00	97.00
Newago	5.50	2.00	0.50	0.50	91.50
Oakland	3.83	8.40	1.44	1.83	84.50
Oceana	4.00	1.00	0.00	0.00	95.00
Ogemaw	3.00	12.00	2.00	1.00	82.00
Ontonagon	4.00	4.00	0.00	0.00	92.00
Osceola	4.00	4.00	0.00	0.00	92.00
Oscoda	2.00	9.00	1.00	1.00	87.00
Otsego	2.00	9.00	0.00	3.00	86.00
Ottawa	5.72	12.14	1.57	1.57	79.00
Presque Isle	3.00	9.00	2.00	2.00	84.00
Roscommon	3.00	5.00	0.00	5.00	87.00
Saginaw	4.33	11.67	2.00	2.00	80.00
Sanilac	1.00	13.50	1.50	1.00	83.00
Schoolcraft	5.00	11.00	0.00	1.00	83.00
Shiawassee	8.33	6.00	0.00	1.33	84.34
St. Clair	5.57	9.43	1.43	3.85	79.71
St. Joseph	3.67	10.33	1.00	2.67	82.33
Tuscola	4.00	13.00	0.50	5.00	77.50
Van Buren	5.67	8.33	1.67	2.67	81.66
Washtenaw	4.42	3.84	0.33	0.08	91.33
Wayne	5.06	8.60	0.87	1.87	83.60
Wexford	2.00	3.00	0.00	1.00	94.00

TABLE 8
1971 MICHIGAN TREAD WEAR AND SNOW TIRE SURVEY

Tire Classification	Passenger Cars	Pickup and Panel Trucks	4-Wheel Drive Vehicles
one half-smooth	0.005	0.001	0
two half-smooth	0.003	0	0
one smooth	0.040	0.024	0.007
two smooth	0.081	0.071	0.004
three smooth	0.008	0.005	0
four smooth	0.018	0.024	0.005
with smooth tires	0.155	0.125	0.029
without smooth tires	0.845	0.875	0.971
with snow tires	0.438	0.651	0.870
without snow tires	0.562	0.349	0.130

APPENDIX A

DEVELOPMENT OF SAMPLING PLAN FOR TIRE STUD SURVEY

It is known that tire stud use varies greatly between areas of the State, probably as a function of average snow fall, character of terrain (hilly or flat), and economic condition. Therefore, one Statewide estimator of the proportion of vehicles with tire studs would not be as accurate for investigating wear on a given highway as would a local estimator. The Statewide estimator could be heavily weighted by large population centers and might not be a good indicator for a county such as Houghton which has high snowfall, hilly terrain, but a relatively small number of vehicles. Therefore, it appears that stratified sampling would be appropriate, with each strata contributing to a Statewide estimate of parameters but also serving as a local estimator. Since vehicle registration data are available for each of Michigan's 83 counties the State will be stratified into counties and registration data will be used for determining sample size and allocation.

Moreover, each item in the sample will be classified simply as to whether it does or does not have tire studs, so the situation is a natural for sampling for proportions. The 1969-1970 survey indicated that variations in proportions of vehicles with studded tires was great enough between counties to warrant a Neyman allocation, rather than proportional, since variance is a function of proportion (p). Therefore, the results of the 1969-1970 survey will be used in allocating the sample.

To summarize: the sample space will consist of all automobiles registered in Michigan; for estimates of county parameters, the sample space will be all automobiles in the county, elementary units will be automobiles, the random variable x_{hj} takes on values of 1 if an automobile j in county h has studded tires or 0 if not, and the vehicle registration list, at least initially, is the sampling frame. Statistical parameters will be estimated.

Statewide Estimation

For a first estimate of total sample size, the finite population correction (fpc) will be ignored and the expression will be:

$$n_o = \frac{1}{N^2} \frac{\left(\sum_1^{83} N_h \sqrt{p_h q_h}\right)^2}{V}$$

where:

n_o	=	number of automobiles in total sample
N_h	=	number of automobiles registered in county h
N	=	number of automobiles registered in state
p_h	=	estimated fraction of automobiles in county h with studded tires
q_h	=	estimated fraction of automobiles in county h without studded tires $(1 - p_h)$
V	=	desired variance

let the desired confidence level = 95 percent

the desired precision = 0.02 (2%)

then:

$$V = \left(\frac{0.02}{1.96}\right)^2 \cong (0.01)^2 = 0.0001$$

After n_o is computed, a corrected value of total sample size (n) will be computed:

$$n = \frac{n_o}{1 + \frac{1}{NV} \sum_{h=1}^{N} W_h p_h q_h} = \frac{n_o}{1 + \frac{1}{N^2 V} \sum N_h p_h q_h}$$

The preceding allocations are not exact since two stage cluster sampling for proportions is to be used within each stratum. However, simple random sampling (SRS) will be assumed for this first estimate which is based on data from last year. For next year's survey, better estimates of parameters should be available to aid in making a more precise allocation.

The proportion of automobiles in the sample space (State) will be estimated by:

$$\hat{p}_{st} = \frac{1}{N} \sum_{h=1}^{83} N_h p_h$$

where:

N_h	=	number of automobiles in stratum h
p_h	=	proportion of automobiles with studded tires in stratum h
N	=	number of automobiles in sample space

For reasons discussed later, two stage cluster sampling will be used within each stratum. The variance of an estimated population total (X) is estimated by:

$$\hat{V}(\hat{X}) = \sum^{L} M_h^2 \frac{M_h - m_h}{M_h} \frac{s_h^2}{m_h} + \sum^{L} \frac{M_h}{m_h} \sum^{m_h} N_{hi}^2 \frac{N_{hi} - n_{hi}}{N_{hi}} \frac{s_{hi}^2}{n_{hi}}$$

and since $P_{st} = \frac{X}{N}$, the preceding expression can be multiplied by $\frac{1}{N^2}$ to determine $V(P_{st})$.

where:

M_h = number of clusters or primary sampling units (psu) within stratum h from which m_h sample clusters or secondary sampling units (ssu) are selected.

s_h^2 = represents variation between psu within county h

s_{hi}^2 = represents variation within the i th psu of stratum h

N_{hi} = number of ssu in psu i of county h

n_{hi} = number of ssu taken from psu i of county h

L = number of counties = 83

Within County Estimations

Using the preceding steps an estimate can be obtained, valid Statewide, of the proportion of automobiles using studded tires. Another equally important goal is to estimate, with desired precision and accuracy, the proportion of automobiles with studded tires within each county.

For survey efficiency, clusters will be selected by randomly selecting primary sampling units (psu) which will be towns or cities within each county. Surveyors will be instructed to travel to each designated town or city and inspect the first cluster consisting of a given number of automobiles that they encounter, which are parked on a public street or parking lot. This cluster, inspected by surveyors, will be the ssu. All ssu within any given county will be equal and will consist of n automobiles.

Obviously all automobiles in every county are not located exclusively in towns or cities. Therefore, samples will be biased in favor of automobiles located in cities or towns during workdays when surveys are made.

For a preliminary estimate of the number of automobiles to be sampled in each county, the following expression will be used:

$$n_h = \frac{N_h Z^2 p_h q_h}{N_h d^2 + Z^2 p_h q_h}$$

n_h = sample size in number of automobiles for county h

N_h = number of automobiles in county h

p_h = proportion of automobiles with studded tires in county h

q_h = $(1 - p_h)$

d = desired precision of estimate (= 0.02 in this case)

Z = number of standard deviates to give desired confidence level. In this case, desired confidence level is 95 so Z = 2.

Although the above formula is not exact for our survey, since it applies to SRS without replacement, it will give us an approximate sample size.

In order to obtain an unbiased estimate of P_h for each county, towns or cities will be selected randomly with probability proportional to size, with replacement (pps wr). Data listing the number of automobiles located in each city or town cannot be obtained without great difficulty so cities or towns will be weighted, for probability of selection, by population count. It appears reasonable to assume that, within each county, population is directly related to number of automobiles.

Then an unbiased estimator of P_h is:

$$\hat{P}_{h_{pps\ wr}} = \frac{1}{m} \sum_{i=1}^{m} p_i$$

and the variance is estimated by:

$$\hat{V}\left(\hat{P}_{h_{pps\ wr}}\right) = \frac{1}{m} \frac{1}{m-1} \sum_{i=1}^{m} \left(p_i - \hat{P}_{h_{pps\ wr}}\right)^2$$

where:

m = number of psu

p_i = proportion of vehicles having studded tires in ssu from cluster (psu) i

$$p_i = \frac{1}{\bar{n}} \sum_{j=1}^{\bar{n}} x_{ij}$$

x_{ij} = car j in cluster (psu) i

$\bar{n}$ = number of cars in ssu.

Details

Surveyors will work in pairs, one recorder and one inspector. A broom or brush will be carried by each pair to clean snow or mud-covered tires where necessary. A letter, describing the survey and written with Department letterhead, will be carried by each team in case they are confronted by police, parking lot guards, etc., while inspecting automobiles. Where parking lots are conspicuously guarded, the letter will be presented and permission requested before beginning the survey.

Survey forms, similar to the one attached, will be used for recording data with one form being used for each cluster.

Remarks

Table 9 lists the total sample size and Neyman allocation of the sample for each county. This was determined on the basis of sampling sufficient to estimate parameters for the State as a whole. For many counties, the sample size is unrealistically small, less than one vehicle for some counties. If this sample allocation were to be used in the survey, each county should be examined and the sample size increased in almost every case, especially since costs for sampling elementary units are so small, once the surveyors have traveled to the area. However, as seen in the following, a much larger sample is required to estimate parameters for each county.

Table 10 lists sample sizes appropriate for surveys to estimate individual county parameters. In the case of the Statewide estimate, a total sample size was first determined (1005 automobiles in this case) and then allocated to each county. For county estimates, sample sizes necessary to obtain desired precision were estimated for each county and these values were summed to give the total for the State (92,256 in this case). Thus, for equal precision in the survey, it would take a sample about 92 times as large to estimate parameters valid for each county as it would if only Statewide parameters were estimated.

In the case of the individual county survey (Table 10), samples for each county are too large to be practical in many cases. For example, Keweenaw County (No. 42) only has 837 registered automobiles. Yet a sample size of 612 is necessary to give a 95 percent confidence of precision within 2 percent. For the actual survey, a modified version of the Table 10 allocation will be used. Counties will be grouped by similar numbers of automobile registrations and separate precisions established for each group. To illustrate why a precision in percent would not have to be identical for each county, an error of 10% in the estimated proportion of studded tire vehicles in Wayne County would be much more serious than in Keweenaw in estimating repetition of studded tires traveling over a pavement. Details and results of the sample survey actually used are listed in Table 6.

REFERENCES

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TABLE 9
SAMPLE ALLOCATION FOR DETERMINATION OF PROPORTION OF VEHICLES IN STATE USING TIRE STUDS

County	Registered Vehicles	Proportion With Studs	Required Sample
Alcona	3886	0.11	0.99
Alger	3270	0.30	1.22
Allegan	27901	0.17	8.57
Alpena	13432	0.08	2.88
Antrim	5168	0.25	1.82
Arenac	4467	0.14	1.26
Baraga	3231	0.30	1.20
Barry	14301	0.23	4.89
Bay	50619	0.08	11.25
Benzie	3830	0.23	1.31
Berrien	78346	0.13	21.06
Branch	15912	0.09	3.61
Calhoun	65290	0.10	16.09
Cass	19065	0.13	5.21
Charlevoix	6974	0.18	2.18
Cheboygan	6931	0.23	2.37
Chippewa	11691	0.16	3.48
Clare	6722	0.20	2.19
Clinton	16667	0.10	3.97
Crawford	2911	0.25	1.02
Delta	14653	0.21	4.81
Dickinson	10815	0.24	3.75
Eaton	27415	0.08	6.04
Emmet	8261	0.33	3.16
Genesee	195742	0.09	45.09
Gladwin	5249	0.11	1.33
Gogebic	8575	0.17	2.62
Grand Traverse	19371	0.22	6.52
Gratiot	16784	0.16	4.94
Hillsdale	16209	0.09	3.77
Houghton	12659	0.42	5.08
Huron	15225	0.19	4.80
Ingham	115471	0.13	31.35
Ionia	18462	0.18	5.76
Iosco	9432	0.07	1.96
Iron	6118	0.12	1.62
Isabella	13974	0.16	4.11
Jackson	62310	0.07	12.48
Kalamazoo	86705	0.18	27.12
Kalkaska	2411	0.22	0.81
Kent	185857	0.18	57.86
Keweenaw	837	0.35	0.32
Lake	2254	0.10	0.55
Lapeer	19530	0.07	3.91
Leelanau	4460	0.17	1.36
Lenawee	36526	0.05	6.47
Livingston	22829	0.15	6.56
Luce	2374	0.29	0.88
Mackinac	3525	0.18	1.10
Macomb	282989	0.09	65.82
Manistee	8950	0.24	3.11
Marquette	24144	0.40	9.63
Mason	9652	0.19	3.08
Mecosta	9995	0.16	2.98
Menominee	10607	0.09	2.47
Midland	29150	0.15	8.46
Missaukee	2795	0.25	0.98
Monroe	50784	0.06	9.93
Montcalm	17672	0.12	4.67
Montmorency	2418	0.10	0.59
Muskegon	68258	0.18	21.46
Newaygo	12423	0.26	4.40
Oakland	432637	0.11	110.40
Oceana	6638	0.25	2.34
Ogemaw	5116	0.17	1.56
Ontonagon	4174	0.12	1.10
Osceola	6262	0.20	2.04
Oscoda	2030	0.13	0.55
Otsego	4562	0.18	1.42
Ottawa	55505	0.19	17.75
Presque Isle	5149	0.09	1.20
Roscommon	5298	0.19	1.69
Saginaw	92725	0.09	21.20
Sanilac	14304	0.14	4.03
Schoolcraft	3619	0.30	1.35
Shiawassee	26421	0.13	7.30
St. Clair	50958	0.08	11.23
St. Joseph	22152	0.10	5.40
Tuscola	19292	0.22	6.44
Van Buren	24204	0.16	7.21
Washtenaw	97229	0.10	24.14
Wayne	1178938	0.10	283.43
Wexford	9101	0.24	3.16
TOTAL			1005.22

TABLE 10
SAMPLE ALLOCATION FOR DETERMINATION OF PROPORTION OF VEHICLES USING STUDDED TIRES IN EACH COUNTY

County	Registered Vehicles	Proportion With Studs	Required Sample
Alcona	3886	0.11	781.99
Alger	3270	0.30	1278.77
Allegan	27901	0.17	1357.96
Alpena	13432	0.08	659.68
Antrim	5168	0.25	1375.83
Arenac	4467	0.14	948.38
Baraga	3231	0.30	1272.76
Barry	14301	0.23	1575.85
Bay	50619	0.08	736.86
Benzie	3830	0.23	1211.02
Berrien	78346	0.13	1078.69
Branch	15912	0.09	741.51
Calhoun	65290	0.10	907.16
Cass	19065	0.13	1067.66
Charlevoix	6974	0.18	1218.18
Cheboygan	6931	0.23	1410.57
Chippewa	11691	0.16	1205.42
Clare	6722	0.20	1292.38
Clinton	16667	0.10	817.58
Crawford	2911	0.25	1140.44
Delta	14653	0.21	1466.63
Dickinson	10815	0.24	1560.77
Eaton	27415	0.08	716.76
Emmet	8261	0.33	1744.18
Genesee	195742	0.09	800.10
Gladwin	5249	0.11	825.11
Gogebic	8575	0.17	1211.63
Grand Traverse	19371	0.22	1576.36
Gratiot	16784	0.16	1214.94
Hillsdale	16209	0.09	779.61
Houghton	12659	0.42	2042.88
Huron	15225	0.19	1371.89
Ingham	115471	0.13	1105.47
Ionia	18462	0.18	1366.73
Iosco	9432	0.07	608.97
Iron	6118	0.12	900.56
Isabella	13974	0.16	1197.51
Jackson	62310	0.07	601.88
Kalamazoo	86705	0.18	1456.86
Kalkaska	2411	0.22	1002.49
Kent	185857	0.18	1456.16
Keweenaw	837	0.35	611.88
Lake	2254	0.10	643.18
Lapeer	19530	0.07	589.41
Leelanau	4460	0.17	1071.89
Lenawee	36526	0.05	468.90
Livingston	22829	0.15	1186.72
Luce	2374	0.29	1102.65
Mackinac	3525	0.18	1040.37
Macomb	282989	0.09	816.64
Manistee	8950	0.24	1515.20
Marquette	24144	0.40	2188.37
Mason	9652	0.19	1327.36
Mecosta	9995	0.16	1184.70
Menominee	10607	0.09	760.30
Midland	29150	0.15	1221.57
Missaukee	2795	0.25	1122.19
Monroe	50784	0.06	572.41
Montcalm	17672	0.12	996.46
Montmorency	2418	0.10	655.88
Muskegon	68258	0.18	1464.88
Newaygo	12423	0.26	1647.77
Oakland	432637	0.11	983.77
Oceana	6638	0.25	1462.03
Ogemaw	5116	0.17	1105.97
Ontonagon	4174	0.12	842.78
Osceola	6262	0.20	1274.38
Oscoda	2030	0.13	726.33
Otsego	4562	0.18	1115.19
Ottawa	55505	0.19	1505.68
Presque Isle	5149	0.09	706.61
Roscommon	5298	0.19	1192.57
Saginaw	92725	0.09	785.13
Sanilac	14304	0.14	1110.53
Schoolcraft	3619	0.30	1328.89
Shiawassee	26421	0.13	1106.91
St. Clair	50958	0.08	725.52
St. Joseph	22152	0.10	864.86
Tuscola	19292	0.22	1551.98
Van Buren	24204	0.16	1273.30
Washtenaw	97229	0.10	924.55
Wayne	1178938	0.10	874.45
Wexford	9101	0.24	1519.47
TOTAL			92255.79