

SKID RESISTANCE IMPLEMENTATION STUDY

Prepared by

**New Jersey Department of Transportation
Bureau of Research**

In Cooperation with

**U. S. Department of Transportation
Federal Highway Administration**

May 1994

1. Report Number FHWA/NJ - 94 - 002 - 7750	2. Government Accession Number	3. Recipient Catalog Number	
4. Title: Skid Resistance Implementation Study		5. Report Date May 1994	
7. Author: Research Staff (See Item 15)		6. Performing Agency Code N/A	
9. Performing Agency Name and Address New Jersey Department of Transportation 1035 Parkway Avenue Trenton, NJ 08625		8. Performing Agency Report Number 94 - 002 - 7750	
12. Sponsoring Agency Name and Address Federal Highway Administration U. S. Department of Transportation Washington, DC		10. Work Unit Number (TRAIS) N/A	
15. Supplementary Notes This report has been compiled by R. Weed from previous reports and notes of K. Diringer, R. Barros, B. Margerum, K. Shelat, and J. Salt.		11. Contract or Grant Number NJ SPR Study 7750	
		13. Type of Report/Period Covered Final	
		14. Sponsoring Agency Code	
16. Abstract The initial objectives of this study were to (1) evaluate various surface texturing procedures for concrete pavement, (2) gather additional data to check the seasonal adjustment for field skid measurements, (3) develop a laboratory test method for prequalifying aggregates on the basis of expected terminal skid resistance, (4) explore the possibility of in-house calibration of the Department's skid test equipment, and (5) perform a life-cycle cost analysis for the skid resistance performance of NJDOT bituminous surface course mixes. Several texturizing procedures and requirements were field tested as part of Task 1, making it possible to develop a prototype specification. An analysis of seasonal data under Task 2 has identified a sine-wave function to predict variations in skid resistance as a function of calendar date. Several tests and correlation studies were conducted under Task 3 to develop a prequalification procedure for surface course aggregates based on laboratory polishing tests. The investigation under Task 4 led to the conclusion that it was more practical to continue to have the calibration of the skid test equipment performed by an outside laboratory. Due to a downsizing of the research organization during the course of this study, and the reassignment of the principal investigator and several members of staff, Task 5 was dropped.			
17. Key Words Skid resistance, aggregate polishing		18. Distribution Statement	
19. Security Class (This Report) Unclassified	20. Security Class (This Page) Unclassified	21. Total Pages 26	22. Price

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily represent the official views or policies of the New Jersey Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

CONTENTS

SUMMARY	1
BACKGROUND	2
TASK 1. CONCRETE SURFACE TEXTURING SPECIFICATION	3
TASK 2. SEASONAL VARIATION OF SKID RESISTANCE	12
TASK 3. PREQUALIFICATION PROCEDURE FOR AGGREGATES	13
TASK 4. CALIBRATION OF SKID TEST EQUIPMENT	21
IMPLEMENTATION AND RECOMMENDATIONS	22
REFERENCES	23

FIGURES

Figure 1. Relationship between laboratory polish value and terminal skid value	15
Figure 2. Data illustrating aggregate acceptance procedure	20

TABLES

Table 1. Risk analysis of several candidate acceptance plans	9
Table 2. Estimation of percent defective (N = 5)	10
Table 3. Estimation of percent defective (N = 10)	11

SUMMARY

The initial objectives of this study were to (1) evaluate various surface texturing procedures for concrete pavement, (2) gather additional data to check the seasonal adjustment of field skid measurements, (3) develop a laboratory test method for prequalifying aggregates on the basis of expected terminal skid resistance, (4) explore the possibility of in-house calibration of the Department's skid test equipment, and (5) perform a life-cycle cost analysis for the skid resistance performance of NJDOT bituminous surface course mixes.

Several texturizing procedures and requirements were field tested as part of Task 1, making it possible to develop a prototype specification. An analysis of seasonal data under Task 2 has identified a sine-wave function to predict variations in skid resistance as a function of calendar date. Several tests and correlation studies were conducted under Task 3 to develop a prequalification procedure for surface course aggregates based on laboratory polishing tests. The investigation under Task 4 led to the conclusion that it was more practical to continue to have the calibration of the skid test equipment performed by an outside laboratory. Due to a downsizing of the research organization during the course of this study, and the reassignment of the principal investigator and several members of staff, Task 5 was dropped.

BACKGROUND

Because pavement skid resistance is a critical factor in motorist safety, the New Jersey Department of Transportation (NJDOT) has conducted several studies in recent years aimed at developing better methods to predict and control this characteristic (1 - 5). This study was initiated to further this work in order to develop appropriate guidelines for the operating units of the Department.

Previous studies have addressed the polishing behavior of aggregates used in asphaltic concrete (AC) and portland cement concrete (PCC) pavements as well as the equipment used to impart surface texture during the construction of PCC pavement. Equipment and test methods used to measure skid resistance have also been studied. It was believed that earlier data, combined with new data to be obtained as part of this study, would be capable of yielding a better understanding of the key factors affecting the performance of different types of aggregate available in New Jersey. It was also desired to develop a procedure for aggregate selection which would allow gradually diminishing supplies to be used in the most advantageous way possible.

The earlier work had indicated that there was a seasonal variation of skid resistance measured in the field that was related to the date of measurement. It was desired to develop a better understanding of this relationship to permit a valid comparison of sections of pavement that might be evaluated throughout the year.

A prototype specification had been developed for the texturing of PCC pavement and bridge decks. This specification is considered to be an improvement over past practices but a further evaluation was judged to be necessary to assure that it is both practical and effective.

Another problem that had to be resolved was the annual calibration procedure for the skid test equipment. Previously, this had to be performed at an independent laboratory in Ohio where the necessary equipment was available. More recently, it was learned that the Ohio laboratory was being acquired by a new owner and there was no assurance that the calibration service was going to continue to be available. It was desired to explore the possibility of developing an in-house capability for this function.

TASK 1. CONCRETE SURFACE TEXTURING SPECIFICATION

Since the 1970s, the NJDOT has experimented with several methods to impart texture to concrete surfaces to achieve greater and longer lasting skid resistance. Construction specifications were revised to require broom finishing rather than the burlap-drag procedure that had been used in the past. More recently, tests have been conducted with both mechanical tining and saw-cut grooving. Two recent reports (6, 7) describe this experience and the prototype specifications that grew out of this effort. The initial surface texture specification is worded as follows:

The surface texture shall be a steel tine finish having a uniform pattern of grooves perpendicular to the centerline, spaced at 1.0 ± 0.125 inch centers, 0.10 ± 0.025 inch wide, and $0.125 - 0.25$ inch deep. A mechanical comb conforming to Subsection 405.03 shall be used to produce the tine finish. The tine finish for the 12 inches of concrete surface adjacent to curbs or raised berms may be omitted.

The tine finish shall be applied when the water sheen has practically disappeared. Finishing shall be completed before the concrete is in such condition that the surface will be torn or roughened by the operation. The finished surface shall be free from rough or porous areas, irregularities, or depressions.

The mechanical comb shall be drawn across the concrete surface at a slow, uniform speed not to exceed 2 feet/second. Successive passes of the mechanical comb shall overlap by no more than 2 inches.

Hand combs with steel tines shall be available at all times for the purpose of providing a surface texture in the event of a breakdown of the mechanical comb. The hand comb shall be drawn from the center to the edge of the concrete at a constant angle with the surface,

exerting constant pressure on the plastic concrete to produce the required uniform texture.

Conformance to the required minimum tine depth of 0.125 inch of the finished concrete surface shall be determined as follows:

Within a lot of approximately 2000 square yards or less, 20 locations will be randomly selected. At each of these locations, a 3-foot square will be marked on the pavement surface. Along the diagonal of the square, 10 tine-depth readings will be taken at approximately equal intervals using a tire tread-depth gauge. An average tine depth will be computed and recorded for each of the 20 locations.

An acceptable lot shall produce a quality index (Q) of 0.15, or greater, where

$$Q = (\bar{X} - L)/S$$

\bar{X} = sample mean, computed from the 20 average values, expressed to the nearest 0.001 inch

L = acceptance limit = 0.125 inch

S = sample standard deviation, expressed to the nearest 0.001 inch.

Should the lot fail to meet the quality index requirement, a retest will be conducted following the same measurement procedure on a new sample of 20 randomly selected locations.

If the retest confirms the lot's failure, then the surface shall be sawcut groove finished. Sawcutting will not be permitted until the concrete pavement has attained a strength of at least 3000 psi as determined from cylinders cast during placement of the pavement or until the pavement is at least 14 calendar days old. Grooves shall be cut perpendicular, radial, or longitudinal to the centerline of the roadway. Grooves shall be rectangular in shape and conform to the following dimensions:

WIDTH = 0.10 - 0.15 inch

DEPTH = 0.25 - 0.375 inch

Grooves shall be spaced at 1.5 ± 0.0615 measured center-to-center. This dimension may be increased up to 3 inches at the end of each pass, as necessary. During remedial texturing, the groove dimensions shall be checked at random. If the minimum depth is not achieved, the necessary adjustments shall immediately be made.

When sawcutting grooves is required, sawing equipment specifically designed and equipped for the

grooving of pavements shall be provided. The saws shall be of a multibladed type, adequate in number of units and power to complete the sawcut grooving operation, equipped with water-cooled, circular, diamond-edge blades and alignment wheels. A system of slurry collection shall be provided. An ample supply of replacement saw blades shall be maintained at the work site during the grooving operation.

The sample size of 20 used for the initial trials of this specification was chosen to be relatively large in order to generate additional data to study the tining operation. The acceptance criteria were intentionally lenient to make sure that acceptable work was not falsely rejected. It is now believed that the sampling rate can be reduced substantially without unduly increasing the risks to either the highway agency or the construction industry and that the acceptance procedure should be strengthened somewhat. The two-stage procedure continues to be regarded as a practical choice because it permits a relatively low frequency of inspection when the quality is running at high levels and, at the same time, it provides an increased level of sampling to justify the decision to require corrective action when the quality level is unsatisfactory.

In order to analyze acceptance procedures of this type, it is first necessary to define two distinct levels of quality, the acceptable quality level (AQL) and the rejectable quality level

(RQL). The AQL is that level of quality that empirical data or engineering analysis have shown will produce satisfactory performance. The RQL is a sufficiently low level of quality that requires some form of corrective action.

The NJDOT has chosen to define the AQL as a lot having no more than $PD_{AQL} = 10$ percent of the surface outside specification limits. It is believed that this level of quality is readily achievable by the construction industry and will assure good performance.

No data was available to precisely establish the level of quality to be defined as rejectable. However, if about 50 percent or more of the surface area is outside specification limits, it is believed that this would substantially shorten the time period throughout which the surface texture is capable of providing adequate skid resistance. The present requirement that the quality index (Q) computed from 20 test values must equal or exceed a value of 0.15 is consistent with this assumption.

In order to evaluate various possible modifications of the current acceptance plan, it is necessary to examine the operating characteristic (OC) curve (8, page 19, Item 6) for any plan that might be considered. A computer program, currently under development for FHWA Demonstration Project 89 on Quality Management (9), proved to be very useful for this step. The primary points of interest are the risks at the AQL and the RQL. The OC curves for several candidate plans were computed and the acceptance probabilities at the AQL and the RQL are listed in Table 1.

Table 1. Risk analysis of several candidate acceptance plans.

PLAN	SAMPLE SIZE		ACCEPTANCE CRITERIA				PROBABILITY OF ACCEPTANCE		OVERALL AVERAGE SAMPLING RATE (TESTS PER LOT)	
	N1	N2	Q1	Q2	PD1	PD2	AOL	ROL	AOL	ROL
A	20	20	0.15	0.15	44	44	1.00	0.43	20.0	35.2
B	10	20	0.54	0.53	30	30	1.00	0.12	10.2	28.8
C	10	10	0.54	0.54	30	30	1.00	0.13	10.1	19.4
D	5	10	0.57	0.54	30	30	1.00	0.26	5.6	13.6
E	5	10	0.72	0.69	25	25	0.99	0.17	6.1	14.1

The columns headed N1 and N2 in this table provide the sample sizes for the first and second series of tests, respectively. Similarly, Q1 and Q2 represent the minimum acceptable values that must be equalled or exceeded by the Q values computed from the two series of tests. In addition to stating the acceptance requirements in the form of minimum Q values, they can also be stated as maximum values of percent defective, PD1 and PD2, as listed in Table 1. In this case, tables such as those presented as Tables 2 and 3 are required to convert the computed Q values to estimates of percent defective before making the acceptance decision. The average sampling rates in the last column of Table 1 are a reflection of the frequency with which the second series of tests is required before the final determination can be made.

Table 2. Estimation of percent defective (N = 5).

Q	VARIABILITY-UNKNOWN PROCEDURE				SAMPLE SIZE		STANDARD DEVIATION METHOD			
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.64	49.29	48.93	48.58	48.22	47.87	47.51	47.15	46.80
0.1	46.44	46.09	45.73	45.38	45.02	44.67	44.31	43.96	43.61	43.25
0.2	42.90	42.54	42.19	41.84	41.48	41.13	40.78	40.43	40.08	39.72
0.3	39.37	39.02	38.67	38.32	37.97	37.62	37.28	36.93	36.58	36.23
0.4	35.88	35.54	35.19	34.85	34.50	34.16	33.81	33.47	33.13	32.78
0.5	32.44	32.10	31.76	31.42	31.08	30.74	30.40	30.06	29.73	29.39
0.6	29.05	28.72	28.39	28.05	27.72	27.39	27.06	26.73	26.40	26.07
0.7	25.74	25.41	25.09	24.76	24.44	24.11	23.79	23.47	23.15	22.83
0.8	22.51	22.19	21.87	21.56	21.24	20.93	20.62	20.31	20.00	19.69
0.9	19.38	19.07	18.77	18.46	18.16	17.86	17.55	17.26	16.96	16.66
1.0	16.36	16.07	15.78	15.48	15.19	14.91	14.62	14.33	14.05	13.76
1.1	13.48	13.20	12.93	12.65	12.37	12.10	11.83	11.56	11.29	11.02
1.2	10.76	10.50	10.23	9.97	9.72	9.46	9.21	8.96	8.71	8.46
1.3	8.21	7.97	7.73	7.49	7.25	7.02	6.79	6.56	6.33	6.10
1.4	5.88	5.66	5.44	5.23	5.02	4.81	4.60	4.39	4.19	3.99
1.5	3.80	3.61	3.42	3.23	3.05	2.87	2.69	2.52	2.35	2.19
1.6	2.03	1.87	1.72	1.57	1.42	1.28	1.15	1.02	0.89	0.77
1.7	0.66	0.55	0.45	0.36	0.27	0.19	0.12	0.06	0.02	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q, THE QUALITY INDEX. FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

Table 3. Estimation of percent defective (N = 10).

Q	VARIABILITY-UNKNOWN PROCEDURE				SAMPLE SIZE 10		STANDARD DEVIATION METHOD			
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.23	48.85	48.46	48.08	47.70	47.31	46.93	46.54
0.1	46.16	45.78	45.40	45.01	44.63	44.25	43.87	43.49	43.11	42.73
0.2	42.35	41.97	41.60	41.22	40.84	40.47	40.09	39.72	39.34	38.97
0.3	38.60	38.23	37.86	37.49	37.12	36.75	36.38	36.02	35.65	35.29
0.4	34.93	34.57	34.21	33.85	33.49	33.13	32.78	32.42	32.07	31.72
0.5	31.37	31.02	30.67	30.32	29.98	29.64	29.29	28.95	28.61	28.28
0.6	27.94	27.60	27.27	26.94	26.61	26.28	25.96	25.63	25.31	24.99
0.7	24.67	24.35	24.03	23.72	23.41	23.10	22.79	22.48	22.18	21.87
0.8	21.57	21.27	20.98	20.68	20.39	20.10	19.81	19.52	19.23	18.95
0.9	18.67	18.39	18.11	17.84	17.56	17.29	17.03	16.76	16.49	16.23
1.0	15.97	15.72	15.46	15.21	14.96	14.71	14.46	14.22	13.97	13.73
1.1	13.50	13.26	13.03	12.80	12.57	12.34	12.12	11.90	11.68	11.46
1.2	11.24	11.03	10.82	10.61	10.41	10.21	10.00	9.81	9.61	9.42
1.3	9.22	9.03	8.85	8.66	8.48	8.30	8.12	7.95	7.77	7.60
1.4	7.44	7.27	7.10	6.94	6.78	6.63	6.47	6.32	6.17	6.02
1.5	5.87	5.73	5.59	5.45	5.31	5.18	5.05	4.92	4.79	4.66
1.6	4.54	4.41	4.30	4.18	4.06	3.95	3.84	3.73	3.62	3.52
1.7	3.41	3.31	3.21	3.11	3.02	2.93	2.83	2.74	2.66	2.57
1.8	2.49	2.40	2.32	2.25	2.17	2.09	2.02	1.95	1.88	1.81
1.9	1.75	1.68	1.62	1.56	1.50	1.44	1.38	1.33	1.27	1.22
2.0	1.17	1.12	1.07	1.03	0.98	0.94	0.90	0.86	0.82	0.78
2.1	0.74	0.71	0.67	0.64	0.61	0.58	0.55	0.52	0.49	0.46
2.2	0.44	0.41	0.39	0.37	0.34	0.32	0.30	0.29	0.27	0.25
2.3	0.23	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.12
2.4	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05
2.5	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.6	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q, THE QUALITY INDEX. FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

It is desired that the probability of acceptance be very close to 1.0 at the AQL, such that good quality work is nearly always accepted, and that the probability of acceptance at the RQL be at some suitably low level. Plan A in Table 1 is the acceptance procedure used for the initial field trials. It will virtually always accept AQL work, as desired, but it is not sufficiently discriminating at the RQL. Because of this, and the fact that the sample size is larger than necessary, a modification is appropriate. Of the remaining plans in this table, either Plan C or Plan E would probably be considered suitable.

TASK 2. SEASONAL VARIATION OF SKID RESISTANCE

Based on earlier studies, it was believed that a bituminous pavement's skid resistance would approach a constant, terminal value after approximately two million vehicle passes and that it would then vary about this asymptotic value as the result of day-to-day and seasonal effects. It was desired to derive a mathematical expression to model this behavior.

Several analyses were performed with a variety of independent variables. The dependent variable, SN40, represents the skid resistance measured with a standard ribbed tire (ASTM E-501) at 40 mph. This test procedure corresponds to ASTM E-274 which is the standard for the NJDOT skid resistance inventory program.

It was originally thought that it might be necessary to develop different relationships for different aggregate types. However, by selecting slightly conservative values for the

coefficients, it was found that a single model could be used for the range of aggregates used in this study. The general form of the model is given by Equation 1.

$$SN_{40} = SN_{\text{TERMINAL}} + B_1 \text{SIN}(B_2(\text{JDAY}) + B_3) \quad (1)$$

where

SN40	=	skid number measured at 40 mph
JDAY	=	Julian calendar day
SN _{TERMINAL}	=	terminal value of skid resistance
B ₁ , B ₃	=	estimated regression coefficients
B ₂	=	a constant (360/365 = 0.986) converting the annual seasonal cycle to 360 degrees)

The amplitude of the seasonal effect (B₁) was found to range between 1.3 and 3.3 so a nominal value of 3.0 was used. The lateral displacement of the seasonal effect (B₃) was found to be about 2 degrees (the equivalent of 2 days) which could be ignored with a negligible loss of precision. This permits universal use of the seasonal adjustment model given by Equation 2 without the necessity of attempting to calibrate it for each aggregate.

$$SN_{40} = SN_{\text{TERMINAL}} + 3.0 \text{SIN}(0.986(\text{JDAY})) \quad (2)$$

TASK 3. PREQUALIFICATION PROCEDURE FOR AGGREGATES

In order to make appropriate decisions in selecting aggregate sources for particular applications, and to use diminishing

resources wisely, a procedure was needed that is capable of predicting terminal skid resistance in pavement surface courses as a function of polish values derived in the laboratory. It was believed that the best aggregates should be reserved for high volume/high speed applications or for areas expected to be problematical based on accident frequencies or geometry. The following general guidelines were previously established (5):

<u>MINIMUM LABORATORY POLISH VALUE</u>	<u>QUALITY</u>
24 or less	Poor
25 to 30	Marginal
31 or more	Good

In order to develop a more rigorous evaluation procedure, data were obtained from 26 field sites, representing terminal skid resistance values ranging from a minimum of about 20 to a maximum exceeding 50. Cores were obtained from these sites and, from these, aggregate samples were obtained upon which laboratory polish tests were performed. Both linear and nonlinear regression models were fitted to this data set and, based on these results, it was concluded that there was no advantage in using other than the linear relationship given by Equation 3. The data and the fitted line are shown in Figure 1.

$$SN_{\text{TERMINAL}} = - 0.5 + 1.37 PV \quad (3)$$

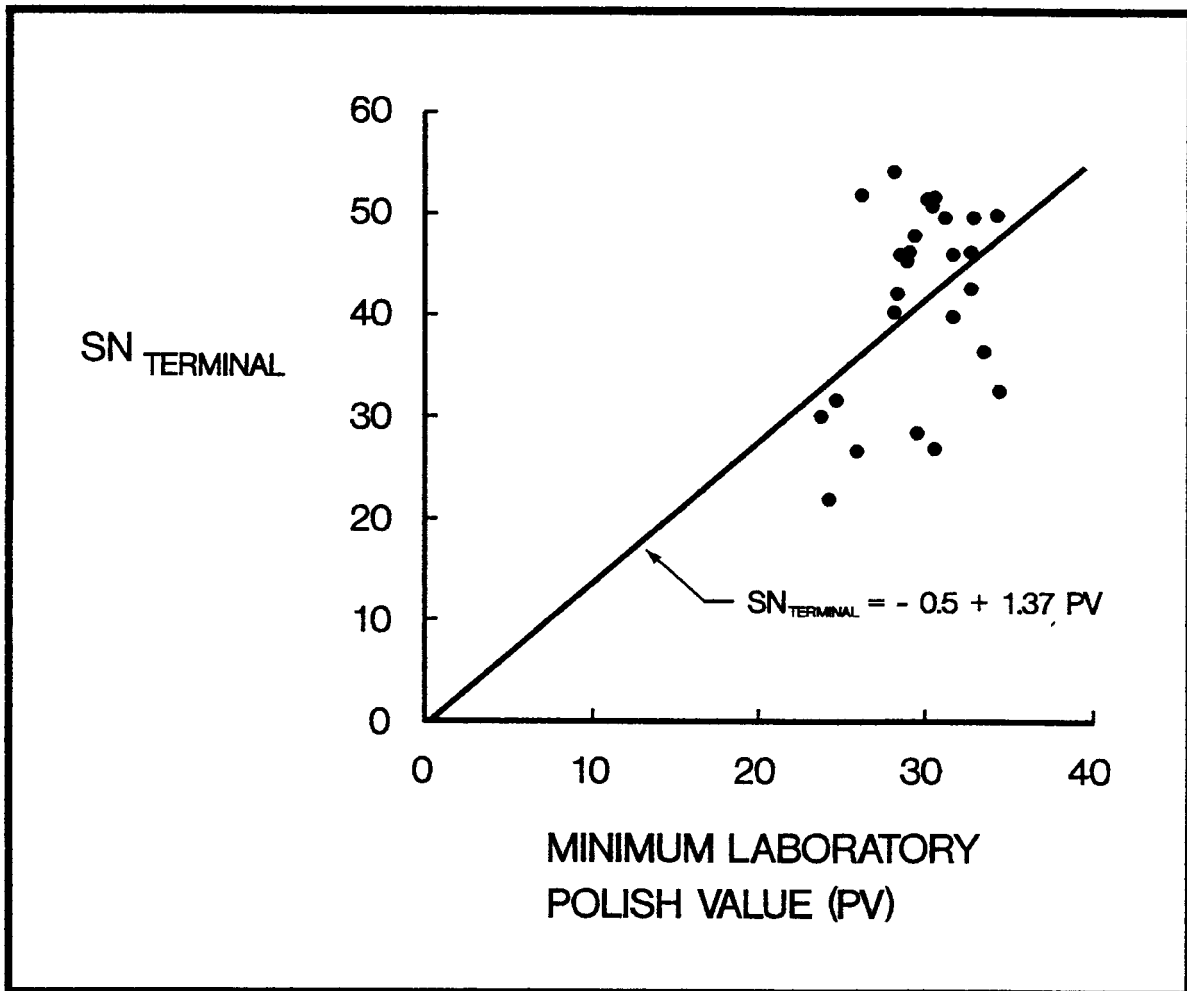


Figure 1. Relationship between laboratory polish value and terminal skid value.

where

- SN_{TERMINAL} = estimated terminal value of skid resistance
measured in the field
- PV = estimated minimum polish value measured in
the laboratory

There are two important observations to be made from this relationship. The first is that the actual terminal value of skid resistance measured on the pavement is always substantially higher than the corresponding laboratory polish value. This is because the laboratory polish value reflects only the characteristics of the aggregate sample measured by laboratory equipment while the pavement value reflects the performance of the complete pavement matrix as measured by field equipment. The second observation is that, for any particular minimum polish value, there is a range of several units over which the resulting terminal skid value might fall.

This information, when combined with the observed seasonal fluctuation of terminal skid value given by Equation 2, can be used to formulate an evaluation procedure capable of predicting the field performance of candidate aggregate samples. It is desired to make the selection so that a pavement's terminal skid value at 40 mph will exceed the desired minimum value of 35. Because the seasonal fluctuations can produce a shift of ± 3 units, it is necessary to raise the desired minimum value from 35 up to 38. For the initial acceptance procedure, the relationship given by

Equation 3 is assumed to be precisely correct and no attempt has been made to account for the variability about the regression line observed in Figure 1. This means that, on the average, an aggregate selected in this manner will provide a terminal skid value of 35, or somewhat more, depending on the seasonal factors. Substituting the minimum terminal value of 38 discussed above into Equation 3 produces a minimum laboratory polish value of 28.

The laboratory acceptance procedure is as follows:

(1) Polish 7 aggregate specimens with the British Polishing Wheel in accordance with ASTM Designation D3319.

(2) Measure the skid resistance of the 7 specimens at 4 specific times -- $t = 0, 1, 2,$ and 4 hours -- with the British Pendulum Tester in accordance with ASTM Designation E303.

(3) Fit a regression equation to these 4 data points of the form

$$y = A + Bx \quad (4)$$

where

y = average laboratory polish value

$x = 1/(t + 1), t =$ test duration in hours

$A =$ constant term obtained from regression analysis

$B =$ regression coefficient

(This can readily be done with a pocket calculator having the necessary statistical capability.)

(4) It is required that the constant A, which represents the minimum laboratory polish value, be greater than or equal to 28.

(5) Run a companion set of tests with a known control aggregate to confirm that the value of A obtained in this manner is within ± 2 units of the expected value to verify that the test procedure is accurate.

The following is an example using typical laboratory results to illustrate this procedure:

TEST DATA (Require $A \geq 28$)

<u>t (Hours)</u>	<u>$x = 1/(t + 1)$</u>	<u>y (Laboratory Polish Value)</u>
0	1.00	45.0
1	0.50	39.7
2	0.33	37.3
4	0.20	35.2

Resulting regression equation:

$$y = 33.2 + 12.0 x \quad (5)$$

Check minimum polish value requirement:

$$A = 33.2; A \geq 28 \quad (6)$$

Conclusion: Satisfactory pending results from control sample.

CONTROL DATA (Require $34 \leq A \leq 38$)

<u>t (Hours)</u>	<u>x = 1/(t + 1)</u>	<u>y (Laboratory Polish Value)</u>
0	1.00	45.8
1	0.50	41.6
2	0.33	39.5
4	0.20	37.9

Resulting regression equation:

$$y = 36.3 + 9.71 x \quad (7)$$

Check minimum polish value:

$$A = 36.3; 34 \leq A \leq 38 \quad (8)$$

Conclusion: Control test is within expected limits.

Although it is not necessary to plot the laboratory polishing curve to apply this procedure, the curve for this test aggregate is shown in Figure 2 for illustrative purposes. This aggregate is clearly satisfactory because it produces a minimum polish value well above the limit of 28 while the control test is within the desired limits. This procedure has been in use for approximately one year and appears to be working satisfactorily. Because this procedure is based on the assumption that Equation 3 is accurate, and the true relationship may be somewhat above or below the regression line shown in Figure 1, this procedure effectively operates at a 50 percent confidence level. At some future time, it may be desirable to consider a revised procedure that provides still greater assurance of achieving the desired terminal skid value.

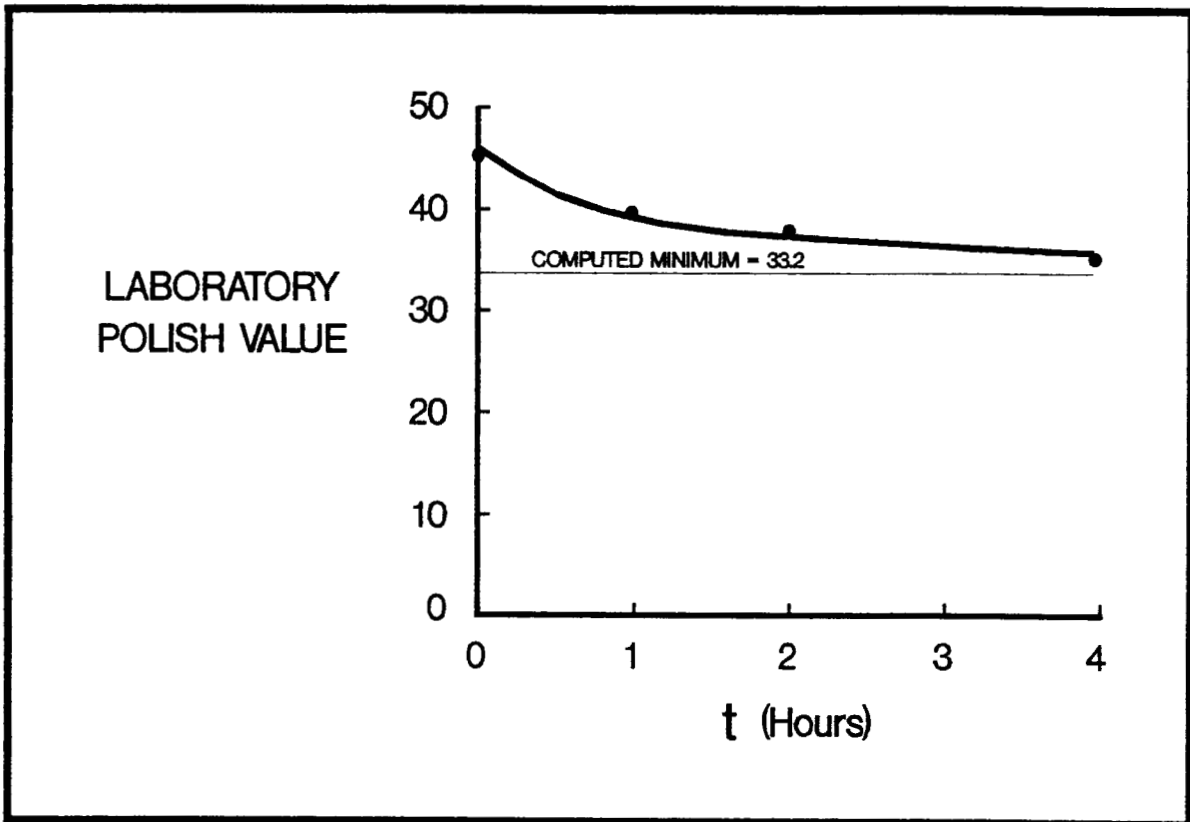


Figure 2. Data illustrating aggregate acceptance procedure.

TASK 4. CALIBRATION OF SKID TEST EQUIPMENT

A vital element of the skid resistance monitoring program is the periodic calibration of the three skid test units. It has been the practice of the NJDOT for many years to drive the units to a private facility in Ohio to obtain this service. This has been done on an annual basis and usually requires a total of three weeks, including travel time.

It had been learned that the Ohio facility was being acquired by a new owner and there was some uncertainty that the calibration service would continue to be provided. Therefore, alternate sources for this service were sought and consideration was given to developing an in-house calibration capability.

Alternate strategies, if necessary, would include contacting surrounding states that use similar equipment to determine if they perform the same type of calibration and, if so, if it would be possible to share the facilities they use. A somewhat less desirable alternative would be to perform correlation studies with skid test equipment that has been calibrated by other agencies. It was learned that in-house calibration would require the construction of a garage-type facility, the purchase of several expensive pieces of equipment, the identification of a section of pavement that can be dedicated to the calibration operation, and some fairly extensive training of staff.

More recently, it was learned that the Ohio calibration facility will remain available to perform this service. Because of the expense and effort involved in the various alternatives that

were considered, and a desire to maintain continuity with the existing program, the decision was made to continue to have the units calibrated at the Ohio facility.

IMPLEMENTATION AND RECOMMENDATIONS

Implementation plans for this study are threefold. It is proposed to continue use of the trial specification for concrete surface texture but with a reduced sampling rate. Table 1 provides examples of acceptance plans that would be suitable and still other plans can be developed, if necessary. The prequalification procedure for aggregates to be used in surface courses, developed as part of this study, appears to be working satisfactorily and should be continued. Consideration should be given to modification of the procedure to function at a somewhat higher confidence level than the current level of 50 percent. Consideration should also be given to the establishment of standard polish samples to serve as controls rather than the present procedure of running a complete set of tests on a control sample of aggregate. And finally, it is recommended that the present calibration process for the skid testers at the remote site be continued. At the same time, an attempt should be made to obtain a firm commitment assuring the continued availability of this service.

REFERENCES

1. J. J. Quinn. Evaluation of Skid Resistant Thin Bituminous Overlays. New Jersey Department of Transportation, 1972.
2. J. J. Quinn. Skid Resistant Characteristics of Carbonate Rock Aggregates. New Jersey Department of Transportation, May 1975.
3. K. C. Afferton. Further Evaluations of Skid Resistance Characteristics of Carbonate Rock Aggregates. New Jersey Department of Transportation, 1978.
4. K. T. Diringer. Polish Resistance of Selected New Jersey Aggregates. FHWA/NJ 86-016-7711, February 1987.
5. K. T. Diringer. Aggregates and Skid Resistance. FHWA/NJ 89-008-7110, March 1990.
6. J. J. Quinn and K. Diringer. Texturing Bridge Decks -- A Final Report. FHWA/NJ-86-009-7703, April 1986.
7. K. Shelat. Experimental Concrete Pavement Tining -- Route I-295, Section 1X. FHWA/NJ-88-008-7703, January 25, 1988.
8. K. C. Afferton, J. Freidenrich, and R. M. Weed. Managing Quality: Time for a National Policy. Transportation Research Record 1340, TRB, National Research Council, Washington, DC, 1992.
9. Demonstration Project 89, Quality Management. Federal Highway Administration, Demonstration Projects Division, Washington, DC, 1993.