National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 49 - SEPTEMBER 1973

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Locked-Wheel Pavement Skid Tester Correlation and Calibration Techniques

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 1-12(2), "Locked-Wheel Pavement Skid Tester Correlation and Calibration Techniques," by W.E. Meyer, R.R. Hegmon, and T.D. Gillespie, The Pennsylvania State University, University Park, Pennsylvania.

THE PROBLEM AND ITS SOLUTION

The skid resistance of wet pavements is one of the critical factors influencing highway traffic safety. The majority of highway agencies in the U. S. measure pavement skid resistance with locked-wheel pavement skid testers in general conformance with ASTM Method E-274. However, it has been demonstrated that the repeatability of measurements by a tester and correlation between testers of this type is generally not adequate, particularly from the standpoint of attainment of national safety goals. The objective of NCHRP Project 1-12(2) was development and verification of methods for improving the ability to measure reliably the skid resistance of wet pavement surfaces with skid testers in conformance with ASTM Method E-274-70.

A degree of uncertainty must be accepted with any measurement due to imperfections in the measurement process and the variability of the item being measured. Skid testers are complex measuring devices containing many components, each contributing to uncertainty in the measured quantity. Pavements have inherent variability caused by the influence of such factors as materials, construction, maintenance, traffic, and the environment. The approach used by The Pennsylvania State University researchers to improve the understanding and reliability of pavement skid resistance measurement involved (a) contacts with skid tester owners to collect information on test equipment and operating procedures, (b) conduct of laboratory and field experiments to determine the effect of specific variables on skid resistance measurement, (c) computer simulation studies on the influence of equipment dynamics on skid tester

performance, (d) development of tentative recommendations for reducing variability in skid resistance measurement, and (e) conduct of a two-week skid tester correlation program to verify and modify the tentative recommendations.

Research has been completed resulting in the identification of major factors influencing pavement skid resistance measurement and the recommendation of techniques for improving the calibration, operation, and data evaluation procedures for locked-wheel skid testers. Methods were also developed for applying statistical concepts to skid resistance measurement programs. During the two-week correlation program, use of the recommended techniques resulted in about a 70% improvement in correlation among the skid testers involved. Implementation of recommendations contained in the report will aid highway agencies in obtaining more accurate pavement skid resistance measurements with existing skid testers and, when combined with operation of the FHWA-sponsored Field Test and Evaluation Centers for skid testers, provide a sound basis for calibration of skid testers that will bring about substantial improvement in their correlation nationwide. Consideration of the recommendations by the ASTM should also result in modifications in ASTM Method E-274, leading to more uniform measurements in the future.

FINDINGS

The primary activity leading to the essential findings of the project was the planning and conduct of a skid tester correlation program held at The Pennsylvania State University, October 2-13, 1972. Nine state highway departments, two universities, and one county provided skid testers and crews for participation in the program. During the first part of the program, each of the 12 testers made five skid tests on each of four pavement surfaces at speeds of 40, 30, 50, and 40 mph, for a total of 80 tests per tester. The average of five tests was considered the measured Skid Number (SN) for a particular speed, pavement surface, and tester. After completion of the first series of tests, tabulation of the data indicated a standard deviation (s_T) of 4.08 from the mean SN for all testers in the condition in which they arrived and operated in accordance with their normal procedures. The range of mean SN values for all testers was as high as 24 for a particular surface. After application of corrective measures, including force and load calibrations, installation of standard water nozzles and ASTM E-17 tires from a single production batch, and procedural adjustments, each tester repeated the entire series of tests. The standard deviation from the mean for the second set of data was reduced to 1.24 and further reduced to 1.04 after application of temperature corrections. Table 1 gives the reduction in standard deviations with the various corrective measures. The difference in SN for each tester for all speeds relative to the mean SN values is shown in Figure 1. The over-all improvement in correlation during the program is illustrated by the differences between the range of values within the 90 percent confidence limits for the uncorrected and corrected sets of data. It is particularly noted that for a portland cement concrete pavement (site 5) and an asphaltic concrete pavement (site 6), the range of SN values was reduced from $\pm$ 10 to $\pm$ 3 by application of the corrective measures. Site 3 was a Jennite surface with a low skid resistance and site 4 was a sand epoxy with a low macrotexture.

The reliability of a skid tester depends on both its precision and its accuracy. Precision is a measure of the repeatability of a single tester and depends on the magnitude of random errors. Accuracy is a measure of correlation among skid testers and depends on the magnitude of systematic errors. An analysis of variance performed on data collected during the correlation program indicates that the precision of skid testers, although not completely satisfactory, is generally better than their accuracy. Table 2 summarizes the influence of both random and systematic errors considered during the study on skid resistance measurements and gives corrective actions.

TABLE 1

REDUCTION IN STANDARD DEVIATIONS WITH VARIOUS CORRECTIVE MEASURES

Corrective Measure	Standard Deviation, s_T
Testers in as-arrived conditions	4.08
Data evaluation procedures corrected	3.25
Uniform watering nozzles and tires mounted	2.83
Force and load calibration	1.53
Correction for zero drift	1.24
Correction for temperature differences	1.04

The factors most responsible for the initial poor correlation, in order of decreasing effect, were (a) force calibration and wheel-load errors (b) data interpretation and evaluation, (c) water systems, and (d) temperature differences.

APPLICATIONS

The skid resistance of a pavement is not an absolute value; it depends on conditions during the test and the method of testing. To achieve better agreement in skid resistance measurement on a nationwide basis, uniform test methods, calibration techniques, and correction procedures are needed. Implementation of the findings of this study will result in substantial improvement in the reliability of skid resistance measurements with locked-wheel skid testers conforming to ASTM Method E-274. Recommendations contained in the report are summarized as follows:

1. Although no major ASTM Method E-274 equipment changes are required, a standardized design for inventory testing is advisable. As a minimum, all testers should use a standard water nozzle, a fifth-wheel-driven speed measuring system, and a speed monitoring device for signaling a departure from the selected speed. Instrumentation must be of high quality and electronic signal averaging equipment is highly recommended.
2. All calibration procedures should be standardized. Platform calibrations should be made routinely and frequently to specified accuracy. At longer intervals, and whenever a malfunction is suspected, the skid tester should be calibrated without the tire. Reduced tolerances and higher accuracy are recommended for wheel-load and water-flow rate calibrations.
3. Periodic dynamic calibration on stable reference surfaces is essential for nationwide correlation. It is anticipated that the FHWA-sponsored Field Test and Evaluation Centers will provide this service.
4. Operating procedures must specify methods of field instrumentation checks. Tolerances on speed and tracking should be set as criteria for rejecting data points.
5. Data evaluation should be done over a minimum of 1.5 sec of a skid and start not sooner than 1.5 sec after brake application. Temperature and speed corrections may not be necessary for the majority of inventory testing. For research testing and detailed evaluation of border-line pavements, corrections should only be applied to data of acceptable reliability.
6. Improved operational procedures and training of operators are effective steps for increasing the reliability of skid resistance measurements.
7. Skid resistance data should be analyzed statistically to determine realistic

TABLE 2
SUMMARY OF FACTORS IN SKID RESISTANCE MEASUREMENT

ERROR SOURCE RANDOM	SYSTEMATIC		MAXIMUM EFFECT	AVERAGE ERROR BAND FACTOR	AVERAGE ERROR BAND SKID RESIST.	CORRECTIVE ACTION	REDUCED ERROR BAND FACTOR	REDUCED ERROR BAND SKID RESIST.
x		Speed holding	At 40 mph ±1.2 SN per mph	±2 mph	±1.5 SN	Speed deviation indicator	±1 mph	±0.8 SN
	x	Speed measurement	Same	±5%	±1.5 SN	Fifth wheel and a) tachometer-generator b) pulse-generator	 ±2% ±0.5%	 ±0.8 SN ±0.2 SN
	x	Water temperature	Negligible					
	x	Air temperature	Indirect effect through pavement and tire temperature.					
x		Pavement or tire temperature	±4%/10°F	Depends on season and geographical region	±2%/10°F	Correction requires accurate skid resist. & temp. measurement		±1%/10°F
x	x	Water film	±1 SN for ±10% varia.	±25%	negligible on most pavements, on some ±2.5 SN	Specify calibration method, reduce tolerance to ±5%	±5%	Negligible on most pavements, on some ±1 SN
	x	Water flow	Strong	Large		Uniform watering system, calibrated flow rate propor. to speed		Negligible
x		Pavement variability, lateral	10 SN	15 in.	±4 SN	Operator awareness	5 in.	±2 SN
x		Pavement variability, longitudinal	7 SN in mile		±2 SN	Number of samples (wheel-locks) per test based on S.D. of tester		±2 SN
x		Conditioning and deterioration	4 SN per day		-2 SN	Run control tests, randomize test sequence, correct data		-1 SN
	x	Tire variability	2.5 SN		±1 SN	Check before use		±0.5 SN
	X	Tire construction	2 SN		±1 SN	Belted tire		±0.5 SN
	x	Tire condition	Within wear range 1 SN		±1 SN	Check for uniform wear		±1 SN
	x	Inflation pressure	1 SN in oper. range	24 to 28 psi	1 SN	Use reliable gauge		1 SN
	x	Wheel-load error	% SN error equal to % weigh. error	±2%	±2%	Use scale of minimum resolution of 5 lb	±0.5%	±0.5%
	x	Wheel-load range	1 SN/100 lb	880 to 1080 lb	2 SN	Reduce range		1 SN
x		Dynamic wheel-load change	2 SN		±1 SN	Avoid aerodynamic loads, wheel-load recording with electronic eval.		±0.5 SN
x	x	Instrumentation	Drift		10% or more	Reliable instrumentation, observing operating procedure		±1 %
	x	Torque calibration	Negligible			See procedure		±0.5%(±2 lb)
	x	Platform calibration	±10%		±4.5%	See procedure		±2%(±5 lb)
x	x	Operating procedure		Controls other error sources		Follow correct procedure		
x	x	Data eval.: Operator	±5 SN		±3 SN	Adequate resolution, corr.operating proc.		±1 SN
	x	Brak.cycle	±2%	Min.cycle 2 sec.	±2%	Optimal filtering increase interval	Min. cycle 3 sec.	±1%
x		Dynamics	Negligible dir.eff.					
		Statiscal control		Repeat tests		Estimate stand.dev. of tester, deter number of repeat tests	Repeat tests	

Skid Number values within prescribed confidence and accuracy limits. Records of tester precision and standard deviations should be developed and maintained.

8. Adherence to ASTM Method E-274 equipment specifications and procedures, including the suggested revisions developed during this study, is essential to improved correlation of skid resistance measurements.

These recommendations have been adequately verified during conduct of the study, particularly the correlation program, and are suitable for immediate implementation by users of locked-wheel skid testers

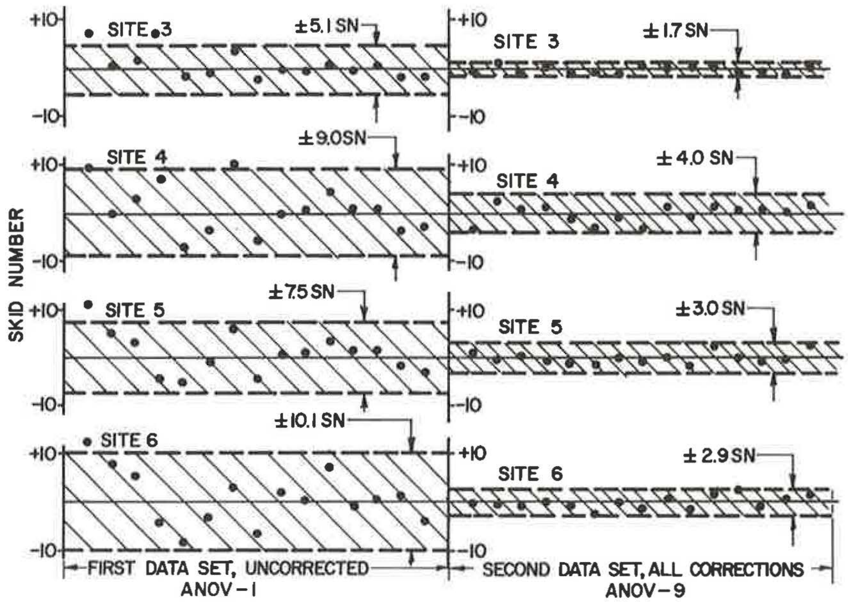

Figure 1. Effect of corrections on variations in SN for each tester at all speeds.

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