DEVELOPMENT AND IMPLEMENTATION OF A PROGRAM TO REDUCE SKID ACCIDENTS

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Provision of skid-resistant pavement surfaces adequate to meet the needs of the motoring public on a wide range of facilities requires a systematic approach. The system employed should have reliable testing procedures to determine friction, criteria to determine corrective action and predictable specifications for surfacing materials to obtain the desired performance. The Pennsylvania Department of Transportation has adopted procedures based on a long history of research and development to obtain an economical and predictable skid resistant performance for pavements. The testing program, correction criteria and specification development using a Skid Resistance Level (SRL) criterion for aggregates is described.

History

The Pennsylvania Department of Transportation has a long history of involvement in research and development in the area of skid resistance. This research work has evolved through development of skid testing equipment and methods in the early 1960's and later to the properties of pavement surfaces necessary to provide adequate levels of skid resistance in the late 1960's and early 1970's. Much of this work was conducted in cooperation with the Pennsylvania State University and is reported under the Joint Road Friction Program. (1, 2)

Joint Industry-Department Skid Task Force

By 1968 it was recognized that friction values of bituminous concrete pavements were governed primarily by the properties of the coarse aggregate particles used in the mix. Specifications had required natural siliceous sand in portland cement mixes and this had been adequate to minimize friction problems with concrete pavements.

A review of the information available showed that pavements constructed with Pennsylvania's gravels and sandstones were considerably higher in friction than those constructed with carbonate aggregates. The information had been collected using broad descriptive terms to group aggregates in categories such as gravels, slags and stones. The performance of these could be compared to show relative averages, however a broad range of values occurred within each group.

Even with similar pavements constructed with aggregate from the same source, the measured friction was affected by variations in traffic rate, mix design, and conditions during testing.

It was apparent that the aggregate parameters needed a better definition in specification terms in order to construct pavement surfaces that would utilize each aggregate source to the fullest extent possible, give adequate friction for the life of the particular pavement and eliminate those aggregates which would polish. Because of the broad impact that changes in aggregate specifications would have, a Joint Industry-PennDOT Skid Task Force was formed. The Task Force was assigned the objective of developing requirements for construction and maintenance of pavements to obtain adequate levels of friction for the particular facility.

1968-69 Test Strips

Under the auspices of the Task Force, eleven pavement strips were planned and constructed in 1968-69. (3, 4) The test strips included a representative cross-section from the more than 340 sources producing approved aggregates in Pennsylvania. The carbonate group was selected as the "control" since this group overall had the poorest skid history. The test strips were constructed as a part of normal planned resurfacing projects, using a dense graded bituminous mixture of minus 1/2" sieve. They included 156 sections using 64 sources of aggregates in 44 miles of pavement.

A comprehensive record of the mix designs, petrographic properties of aggregates, and friction history was collected until 1974.

Requirements Adopted

In 1975 PennDOT specifications were adopted to govern the use of aggregates, based on the properties of an individual source, and to provide adequate skid resistance for the particular pavement being constructed.

Testing Program

In order to support the data requirements for a sizeable research effort and to address the problem of finding and correcting inadequate surfaces, suitable testing equipment and test site selection methods are needed.

Testing Equipment

The Department operates four single wheel testers in accordance with ASTM Method E-274. The testers are operated routinely and continuously to meet all types of testing needs. Two of the testers were at the Ohio test center for correlation in 1975. Upon their return, the practice of correlating the testers with each other was continued with a greater degree of confidence. It is planned to send one tester annually to the Ohio center and to continue correlation locally.

Test Site Selection

Skid tests are performed to meet the needs of a number of programs. PennDOT is responsible for a 45,000-mile highway system ranging from the Interstate system to rural, low-volume, farm-to-market roads.

The individual programs consist of:

1. Wet pavement accident survey.
2. Special request testing.
3. Research project skid testing.
4. Routine survey testing.

The wet pavement accident survey (WPA) is directly related to locating and testing suspect pavements. The test sites are selected from computer analysis of stored data from accident reports. (5) Corrective actions are scheduled as required.

Special request testing is conducted in response to field requests where pavement surfaces are suspect. They usually originate where recent accident data indicate a problem might exist with the pavement or where experienced observers note an irregular appearance.

The 1975 WPA survey computer printout identified 1,716 sites. The site selection criteria were at least five wet-pavement accidents in a three-year period within a 3,000-ft. section. The wet-pavement accidents were also to be at least 30% of all accidents. Sites were eliminated where prior remedial action had been taken or programmed. In some cases no tests could be run due to traffic congestion. Tests were performed on 1,511 sites with 39% indicating correction was required.

A program is also maintained to skid test pavements for municipalities. Testing is planned on the basis of accident frequency data. The test results are reported to responsible municipal officials, and advice for corrective action is offered.

The research project testing is directed at a continuing effort to better clarify pavement friction properties and in support of research efforts with other objectives where skid tests give useful data or augment the evaluation of the project.

Routine surveys are conducted as manpower and equipment are available. This is done on a system basis with the Interstate system receiving top priority.

Correction of Pavements with Low Skid Resistance

Objective

The objective of the total program is to reduce the number and/or severity of traffic accidents. The Federal Highway Safety Program Standard 12 states that each state shall have a program "... for correction of locations or sections of streets and highways with low skid resistance and high or potentially high accident rates susceptible to reduction by providing improved surfaces."

This can often be done by simply providing a new, higher friction surface. At other sites this may not be a complete or permanent solution. A team of highway designers, traffic engineers, safety specialists and maintenance personnel should review the site and determine if other improvements are required. This may include the addition of superelevation, wider shoulders, different or improved signing, improved guardrail placement, pavement markings, or removal of sight obstructions.

Skid Resistance Test Results Action

Corrective measures are the responsibility of the eleven District offices of PennDOT. District personnel are supplied guidelines for the type of pavement surface corrective measures that might be employed.

Skid test results are reported to the Districts with corrective work to be performed in accordance with criteria derived from NCHRP Report 37. (6) The policy is summarized in Table 1.

Table 1. Corrective action policy.

Category	Skid Number (SN40)	Existing Wet Pavement Accident Problem	Action by Engineering District
A	30 or below	Yes	Immediate corrective action
B	31 to 34	Yes	Corrective work as soon as fiscally possible
C	30 or below	No	Same as B with second priority
D	31 to 34	No	Maintain accident surveillance and take corrective action as necessary
E	35 to 40	Yes	Same as D
F	35 to 40	No	Maintain surveillance for future retesting
G	41 or above	--	No action required

Skid test results used to determine the action required and the average for the number of cycles reported for a uniform pavement surface.

Where occasional low test results are reported for a short section of a uniform surface a field review is required to determine the reason.

There are also occasions where tests are run at other than the standard 40-mph speed (SN_{40}). In these cases the results are reported in accordance with Table 1 of NCHRP Synthesis 14. (7)

Responsibilities

The Assistant District Operations Engineer is responsible for coordination of the District team to assure that when corrective measures are taken, all hazardous features at the location are identified and corrected. Standards are provided the District review team to cover updating for slopes, pavement superelevation, shoulder buildup, inlet and end wall modifications, and guardrail replacement. Traffic control procedures are also outlined to provide safety to the traveling public during construction.

Pavement Correction Measures

Pavement corrective measures should be carefully considered by the District and the most economical and suitable treatment should be selected for the particular location. Table 2 outlines the corrective measures currently considered for pavements. It is under constant review and refinement as research work and evaluation continue.

An ID-2 dense-graded bituminous concrete is the prevalent corrective surface on both existing concrete and bituminous surfaces. Grooving of concrete pavements is also used to some extent. With the recently enacted law to ban studded tires in Pennsylvania, more extensive use of grooving seems warranted. Other measures are designated experimental in order to develop a field performance and cost history.

Skid-Resistant Surfaces

The requirements adopted in 1975 meet the objectives of utilizing all of our aggregate sources in bituminous surface courses up to the ability of each individual source to provide adequate friction to meet the needs of traffic in both new and overlayed pavements.

These requirements were developed mostly from the test strip program and analysis. It was found in Pennsylvania that friction values go through an annual cycle roughly approximating a sine curve. Low values usually occur in late summer and early fall, with the amplitude dependent on coarse aggregate characteristics and traffic volume. Initial skid resistance measurements were nearly all adequate and not indicative of future performance. The coarse aggregate properties produce the major effect and the petrographic properties of a particular source can be related to its friction values.

Mix Design Practices

Although the coarse aggregate properties have the major influence, attention must also be given to the mix design. Both asphalt content and fine aggregate affect friction properties and must be considered. It should be noted that a conflict exists between mixes designed for long durability and those designed for friction. Some sacrifice in surface life is usually necessary.

As part of the friction requirements adopted by PennDOT, revised mix design procedures were issued. The revisions contained a more complete explanation of the philosophy to be used to obtain "an optimum bituminous mix" with lower asphalt contents and closer attention to voids filled with asphalt. The use of mixes that showed a slight loss of fines or raveling under traffic was encouraged in order to obtain increased surface texture and exposure of course aggregate particles. This would of course result in some reduced durability.

Major attention was given to the revision of requirements for coarse aggregate, which is the most significant contributor to friction. Each of the 350 approved sources of coarse aggregate in Pennsylvania was assigned a Skid Resistance Level (SRL) designation based upon the particular aggregate properties.

Assigning Aggregate SRL Requirements

The SRL designation for an aggregate is based on its performance in properly designed dense-graded bituminous surfaces. (8, 9) The initial data came from the 1968 test strips, where careful determinations of aggregate properties were made. The results of all skid tests taken for any purpose, are used in assigning SRL designations. Each pavement tested is evaluated by an experienced Materials Engineer who prepares a standard report giving aggregate source, date of construction, ADT and pavement surface condition. The skid test results and field evaluation are carefully considered for the time of year tested in rating an aggregate source.

New aggregate sources are assigned SRL ratings in much the same way as existing sources have been evaluated. Petrographic examinations are made of the material and where close similarity is found to an existing source the same rating is given. Where a rock type not previously used is considered the petrographic examination is supplemented with polished stone values obtained with the British wheel and pendulum tests. These are compared with values from previously rated sources. The SRL rating is determined for each source by plotting skid numbers against average daily traffic (ADT) and calculating a regression line. The aggregate SRL letter is established by the ADT at the intercept with a line at the SN_{40} level.

The SRL ratings of the aggregate sources are continually re-evaluated as additional field data are collected. The various types of aggregate used in Pennsylvania generally fall into SRL designations as follows:

E - Excellent	- Gravels with less than 10% carbonate particles, Sandstones
H - High	- Siltstones, Argillites, some Quartzites, Basalts, Gneisses, Granites, Blast Furnace Slags, Gravels with between 10 and 25% carbonate particles.
G - Good	- Most Quarzites
M - Moderate	- Carbonates of Cambrian age, Serpentine
L - Low	- Carbonates younger than Cambrian

Table 2. Guide for corrective measures to restore skid resistance.

	Corrective Measure Concrete Surface	good condition[a]		poor condition[b]
1.	ID-2 Overlay	Yes		Yes
	Thickness	1-1/2"	3"	3"
	Estimated Cost (sq.yd.)	$1.75	$3.25	$3.25
	Life	<8 yrs.	8 yrs.	8 years
2.	Longitudinal Grooving	Yes		No
	Estimated Cost (sq.yd.)	$1.00		
	Life	5 years @ 5000 ADT		
3.	Slurry Seal (Experimental)	Yes(d)		No
	Thickness	1/8" to 3/8"		
	Estimated Cost (sq.yd.)	$1.10		
	Life	4 years @ 10000 ADT		
4.	Open-Graded Friction Course (Experimental)	Yes		No
	Thickness	3/4"		
	Estimated Cost (sq.yd.)	$1.10		
	Life	8 years @ 15000 ADT		
5.	CRCP (Experimental)	No		Yes
	Thickness			6"
	Estimated Cost (sq.yd.)			$12.00
	Life			25 years
6.	Surface Treatment(d)	No		No
	Estimated Cost (sq.yd.)			
	Life			

	Corrective Measure Bituminous	good condition	poor condition
1.	ID-2 Overlay	Yes	Yes
	Thickness	1-1/2"	1-1/2"[c]
	Estimated Cost (sq.yd.)	$1.75	$1.85+
	Life	8 years	8 years
2.	Longitudinal Grooving	No	No
	Estimated Cost (sq.yd.)		
	Life		
3.	Slurry Seal (Experimental)	No	No
	Thickness		
	Estimated Cost (sq.yd.)		
	Life		
4.	Open-Graded Friction Course (Experimental)	Yes	No
	Thickness	3/4"	
	Estimated Cost (sq.yd.)	$1.10	
	Life	8 years @ 15000 ADT	
5.	CRCP (Experimental)	No	No
	Thickness		
	Estimated Cost (sq.yd.)		
	Life		
6.	Surface Treatment(d)	Yes	No
	Estimated Cost (sq.yd.)	$0.40	
	Life	4 years @ 1500 ADT	

(a) Structurally sound, stable joints and cracks, rutting less than 1/2 inch.
(b) Faulting joints and cracks, spalling, rutting more than 1/2 inch.
(c) Plus binder and/or leveling as required; may be reduced to 1" where ADT is less than 5000.
(d) ADT 1500 maximum; above ADT 1000 use SRL-M aggregate.

Each wearing surface advertised for bids has a coarse aggregate requirement for SRL dependent upon current average daily traffic for resurfacing, or anticipated initial daily traffic on new facilities as shown in Table 3.

Table 3. Aggregate SRL requirements.

ADT	SRL (Skid Resistance Level)
20,000 and above	E
5,000 to 20,000	E,H, *Blend of E and M or E and G
3,000 to 5,000	E,H,G, Blend of H and Mor or E and L
1,000 to 3,000	E,H,G,M, Blend of H and L, or G and L, or E and L
1,000 and below	Any

*All blends are 50% by weight.

The Department maintains a publication, Bulletin 13 "Tentative List of Commercial Producers of Coarse Aggregates," and each source listed has an SRL assigned to it.

Continuing Research

A great deal of effort has gone into establishing a total system that appears to be working. The research effort is continuing to broaden the corrective measures that can be used and to develop new materials and methods to build skid resistant surfaces. Research projects are active in evaluating other test modes such as incipient slip and side friction. The parameters of hydroplaning are also being investigated.

A problem exists in interpreting the results of skid tests run during the year and making seasonal adjustments to reflect late summer and early fall levels. Historical data are being reviewed and a representative selection of pavement types is being continuously tested to develop methods to predict low values for the time of year tested.

Summary

Attainment of the objective to provide safe skid resistant pavements adequate to meet the needs of the motoring public requires a systematic approach. The elements of the system should include the ability to reliably determine skid resistance values with dependable test equipment, methods of locating and surveying pavement surfaces, and a means of rating pavement performance. Finally, specifications should provide for economic, predictable, and adequate friction properties through the anticipated life of new surfaces or for surfaces placed as a corrective action.

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