

Methods for Increasing the Harshness of Texture on Old Concrete Pavements

— Canvass of What the States are Doing —

by

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SUMMARY

This report is a compilation of responses from different states setting forth what they are doing to restore the texture and thereby improve the skid resistance of old portland cement concrete pavements. All of the methods reported in use seem to work satisfactorily in certain cases and none seem satisfactory in all cases. Therefore it is necessary to fit the method to the situation. For example, the practice of deslicking concrete pavements by grooving probably should not be used in the northernmost states where studded tires are used extensively, because these tires wear the grooves out so quickly.

Six methods of increasing the harshness of texture were reported: grooving, acid etching, overlays, bush hammering, pavement burning, and scarifying with a bulldozer with steel tips welded onto its tracks. This report lists the methods used by various states and gives an assessment of each method. The bases of the assessment were: (1) whether the method raised the skid resistance or cut down on accidents, or both, and (2) whether it was durable enough to make its use practical.

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INTRODUCTION

The study entitled "Methods for Increasing the Harshness of Texture of Old Concrete Pavements — A Pilot Study" was initiated in an attempt to determine the best methods of deslicking old portland cement concrete pavements that are still structurally sound. The intent was to evaluate methods now in use and to search for new methods that have the possibility of doing a better job. The need for such a study is easily seen in the analyses of numerous skid tests performed on portland cement concrete pavements under wet conditions. From such analyses it has been shown that after accumulated traffic volumes in the range of from 20 to 25 million this type of pavement becomes slippery, ⁽¹⁾ a condition that many concrete pavements relatively recently put into service are approaching. As used here "slippery" refers to a stopping distance number (SN)* of less than 40, the low value permitted on Virginia roads. ⁽²⁾ In a 1969 survey, 40% of the states reported that slipperiness of concrete pavements was a problem. ⁽³⁾ This survey was updated in 1971 and showed 48% of the states reporting skid resistance problems with concrete. ⁽⁴⁾ In 1969 thirty-five states measured skid resistance and in 1971 forty-one did so.

In the working plan for the present study four avenues of investigation were listed as follows: canvass of other states, acid etches, mechanical alteration, and pavement overlays. This report deals only with the first of these, the canvass of states. The other avenues of investigation will be handled in separate reports.

METHOD OF CANVASS

In performing a study where work of the same or a similar nature has been performed elsewhere, it is important to be cognizant of such results, findings, problems, pitfalls, etc. as are available. The usual method of obtaining this type of information is through a literature review; however, in this case the author was certain that many experiments

*SN = 100 x coefficient of friction

had been tried that had not found their way into the literature. For this reason, in addition to the literature review done as part of the working plan, ⁽⁵⁾ a canvass of the states was deemed necessary. The instrument for the canvass was a letter that stated in part:

If your state has rehabilitated old concrete pavements to reduce slipperiness and has prepared a report on the work, we would appreciate receiving a copy; if work has been done and no report has been written, we would much appreciate a brief summary on what you have done.

RESULTS OF CANVASS

The request for information brought responses from 39 states plus the California Division of Bay Tolls, the New York Thruway Authority, Washington, D. C., and Auburn University.

The methods used by the states are discussed below under the following subheading: grooving, acid etches, pavement overlays, and other methods. A section is included for comments from states that responded to the inquiry but who are not at present rehabilitating the skid resistance of their old concrete pavements. A concluding section contains a summary of the survey findings.

Grooving

Nineteen states reported using grooving as a method of imparting a harsh texture to old portland cement concrete pavements. The pertinent information gained from each state is given below.

California

California, one of the first states to groove pavements, issued reports in 1968 and 1972 that described their grooving program (all longitudinal) from its inception through 1968.* These reports contained before and after accident statistics. In the before period 1,133 accidents occurred; in the after period, 904. This is a reduction of 20%, even though during the same period traffic increased by 17%. Wet pavement accidents decreased by 70%, from 535 accidents before grooving to 158 after grooving, despite wetter weather in the after period. The studies indicated that grooving does not affect dry accidents rates one way or the other. Fatal accidents were cut in half. There were 21 fatal accidents in

*California has over 1,200 lane miles of grooved pavement, of which approximately 1,000 lane miles has been complete since early 1968. Some of the current projects are as much as five miles long.

the before period and ten in the after period. The severity of accidents after grooving was about 10% less than the statewide average. Of the nine different grooving patterns studied the 3/4" spaced groove yielded the greatest reduction in accidents. Fourteen of 39 projects had 3/4" spaced grooves. One of their findings that seems pertinent is that treatment should be carried well beyond such highway features as intersections, superelevation runoff, and sag vertical curves. Very little increases in friction values were obtained by grooving. (6)

Colorado

In Colorado, the grooving of concrete pavements to improve surface texture has resulted in a loss of the grooves within two years in the wheel tracks due to studded tire wear. Thereafter, a bird bath effect developed which increased the potential for hydroplaning and made the surface less skid resistant than it was before grooving.

Connecticut

Connecticut reported that accidents decreased the first year after grooving but increased thereafter. It was found that studded tires tend to destroy grooves. The grooves configuration used was 1/8" by 1/8" on one inch centers.

Florida

The grooving pattern used in Florida was transverse, and the results of the study indicated that the skid resistance was not raised significantly. The texturing pattern was not effective as a warning device. (7)

Hawaii

Hawaii gave no results from grooving. Their groove configurations are: width — 1/8" or 7/64"; depth — 3/16"; spacing — 3/4" center to center.

Louisiana

Louisiana reported experimenting with transverse grooving for improving skid resistance on highly polished concrete surfaces, particularly those at intersections. The results were very disappointing in that the wear rate was much faster than anticipated. The pattern used was a sawtooth effect with grooves on 1/8" centers and approximately 1/8" deep. In addition, Louisiana had awarded a contract for longitudinal grooving on a section of I-10 and I-12 in Baton Rouge, but the work had not performed it at the time of this correspondence.

Maryland

In Maryland, an experiment employing longitudinal and transverse grooves was performed on the Jones Falls Expressway (I-83). The grooves were 1/8" deep, 1/8" wide, and spaced 3/4" center to center. The majority were in the direction of traffic flow

the rest, across the lane. In the one and one-half year period following the grooving the percentages of groove depth worn away were as follows:

| | In Wheel Path | Out of Path |
|-----------------------|---------------|-------------|
| Longitudinal Grooving | 40% | 35% |
| Transverse Grooving | 58% | 44% |

The average skid resistance of the grooved sites is approximately 38 and comparable ungrooved sites average approximately 31. Many of the grooved and ungrooved sites are below the minimum skid number of 35 recommended. (8)

Nebraska

Nebraska's experience with grooving has been limited to one site that consisted of longitudinal grooving of a three-lane, six year old section on a curve of I-80 in Omaha in the fall of 1968. Any improvement was short-lived because of the introduction of studded tires in considerable numbers about 1968. Examination of the pavement surface in the spring of 1969 showed the wearing action of the studded tires had removed all evidence of grooving in the wheel track areas, with only some portions still remaining on either side.

New Jersey

New Jersey has grooved two sites having high wet accident rates. No conclusions have been reached about the effectiveness of the grooving since the evaluation is still in progress. The width of the groove on the first job was 0.125" and on the second it was 0.095". The groove was narrowed on the second job because it had been reported that motorcycles and some foreign cars experienced stability problems with the wider grooves.

New York

New York has been cutting longitudinal grooves in concrete pavements for four years in areas with high wet accident rates. The results have been very good in every case. Before and after studies indicate that accident rates have dropped to a level of from 25-50% of the ones prevailing before grooving was done. Grooves are cut .110" wide, 3/16" deep, and are spaced 3/4" apart. They last about five years.

North Carolina

The North Carolina Highway Commission has grooved concrete pavements at four or five locations. No written report has been made of the results achieved. It has been established, however, that accidents decidedly have been reduced in the areas where the concrete pavement was grooved.

Ohio

Ohio has used longitudinal grooving at several interchange ramp locations having frequent accidents and reportedly has improved the accident frequency. It is apparent that

grooving does not appreciably alter the skid number even though marked reductions in accidents are reported. Until such time that the use of studded tires is discontinued, the effective service life of grooving will be short and should be a factor when considering remedial action.

Oregon

In late 1970 Oregon grooved an 0.80 mile, high wet accident section of I-5 referred to as the "Terwilleger Curves" with dramatic results. The road is a six-lane freeway consisting of two 80° curves connected by a 1,300-foot tangent that carries 71,000 vehicles per day. The before and after accident data are for 12-month periods and are as follows:

Annual Wet Accident Experience

| Item | Before Grooving | After Grooving |
|-----------|-----------------|----------------|
| Accidents | 60 | 22 |
| Injuries | 30 | 10 |
| Deaths | 1 | 0 |

As a result of grooving, it can be seen that accidents declined 63% and personal injuries were reduced 67%. In view of the high volumes and the length of the study period, both of these statistics are considered significant.

Pennsylvania

Pennsylvania reported that their longitudinal grooving had reduced accidents.

Texas

Only a few grooving jobs have been done in Texas. These were on short sections where wet weather accidents were a problem. Little improvement in longitudinal skid resistance was found but generally a significant improvement in accident rates occurred. In 1966 a 100-foot test section was grooved transversely. The coefficient of friction before grooving was 0.25 at 40 mph. After grooving the coefficient of friction was 0.58 at 40 mph; forty-five days later it was 0.38, and ten months later it was 0.30. This decrease in the coefficient of friction was attributed to the soft limestone aggregate used in the concrete mixture. (9) Since correspondence indicates that longitudinal grooving is now being used, it appears that the transverse grooving proved unsatisfactory.

Virginia

In Virginia, longitudinal grooves have been used for the past several years at high wet weather accident locations. Although the skid resistance as measured in the conventional manner does not increase noticeably there have been significant reductions in accidents.

Washington

Washington uses longitudinal grooves 3/16" deep, 0.10" wide, on 3/4" on centers. They report some degree of success in their primary objective — reducing the potential for hydroplaning, but find no appreciable increase in texture as measured by an ASTM-type skid trailer.

West Virginia

West Virginia has four grooved sites under study that have gone through one winter. The grooved areas are showing signs of wear in the tire track, which is probably attributable to studded tires. They are uncertain, at this time, if the wear will continue at a rate sufficient to make grooving impractical.

Wisconsin

Between the opening date in November 1966 and the start of grooving in October 1968 (23 months) approximately 50 accidents were recorded on a section of the north-south freeway (I-94) on a curve between West Waterford Avenue and South 6th Street for a rate of about two accidents per month. During seven months following grooving (November 1968 through May 1969) there were two recorded accidents, for a rate of one accident every three months. Most of the pre-grooving accidents occurred during rain or snow — which implies that skidding was involved. The post-grooving accident reports indicated that one may have been caused by a blowout and the second by one vehicle cutting in front of another. The pre-grooving accidents resulted in 22 personal injuries and 45 instances of property damage. This accident record is vivid proof of the effectiveness of longitudinal grooving as a safety measure. Because of studded tire wear, pavements with heavy traffic showed severe signs of surface wear in the wheel paths and in four years the grooves were essentially obliterated. As the grooves wore away, the accident rate — which had been reduced so drastically as a result of the grooving — slowly increased, and remedial action became necessary. Since regrooving would only be worn away again it was decided to overlay the pavement with bituminous concrete. Because of the extraordinarily rapid wear occasioned by studded tires, useful skid measurements were unobtainable.

Acid Etches

Seven states reported having tried acid etches as a method of imparting a harsh texture to old portland cement concrete pavements. The pertinent information obtained from each state is given below.

Louisiana

In 1966, Louisiana tested a material known as SP-3, which had a high hydroflouric acid content (approximately 26 normal). The area tested was 180 feet long by 10 feet wide.

Results of their tests were:

1. The SP-3 produced an increase in the coefficient of friction and a decrease in stopping distance of approximately 25%.
2. At the end of six months under traffic, the SP-3 treatment was approximately 67% as effective as when first applied.
3. Untrained personnel should be cautioned as to the health and safety hazards involved in handling this product.
4. All personnel handling this product should wear goggles, rubber hats, and overclothes, and some type of breathing apparatus so as to avoid inhalation of the vapor.
5. Since this product affects some automotive paints, traffic should not be allowed over the surface until the SP-3 has been neutralized.
6. SP-3 is not recommended for use over bridges where spillage over the side to the structural steel paint film is possible.
7. SP-3 should not be applied on pavement when the surface temperature is above 95° F.

New York

The state of New York has acid etched pavements at three locations. The skid resistance was increased about 20%, however, after a period of six months it dropped to the level it was before the pavement was etched. Acid etching is the cheapest and quickest way to improve pavement skid resistance. However, it is best suited for temporary treatment of slippery pavement conditions.

New York State Thruway Authority

The Thruway Authority is presently acid etching (20° Baume muriatic) a few problem interchange ramps and has used this technique for about nine years at various locations. The skid resistance increases from a wet coefficient of friction of about 0.25 to about 0.50 after treatment. While etching increases the microtexture, some part of the improvement in skid resistance is due to the removal of grease and oil deposits. In either case the gain in skid resistance is temporary and is lost in about six months.

North Carolina

Experimentation was carried out in North Carolina using an application of acid, however, no report or conclusions were submitted in the canvass.

Ohio

Acid etching was one of the early methods attempted to provide improved skid resistance in Ohio. This method is very practical from an economic standpoint and can be accomplished between peak traffic periods to avoid interference with the traveling public. Acid etching has been found to result in an increase in skid numbers of about 20. However, the skid number diminishes in subsequent months due to the action of traffic. The improved skid resistance has a life of about three to six months, depending upon the volume of traffic. There is merit in this method in spite of the short life span because it allows treatment in the fall to provide improved safety to motorists during the critical winter months. The strength of the acid used in initial explorations was varied from full strength to half acid and half water. No appreciable benefits could be observed for the full strength; therefore, the 50-50 mix using 20 degree Baume scale acid was adopted for all acid etching.

Texas

In the spring of 1967 the Texas Highway Department tested SP-3 on a portland cement concrete pavement. Skid tests were performed before and after treatment with a skid test trailer and a British portable tester. Little improvement was found.

Virginia

In 1969 the Virginia Highway Research Council experimented with acid etching as a method of deslicking old concrete pavements. Table 1 shows the results of that experimentation:

Table 1

Skid Test Data Before and After Acid Etching in Virginia⁽¹⁰⁾

| Type of Treatment | Ratio Water/Acid | 40 Miles Per Hour Predicted Car Values | | |
|--------------------------|------------------|--|--|---|
| | | Mean Before Treatment 10/21/69 | Mean 1 Day After Treatment 10/23/69 | Mean 6 Months After Treatment 4/7/70 |
| No Treatment (Control) | | 45 | 47 | 46 |
| SP-3 ^a (Acid) | 4-1 | 45 | 62 | 47 |
| Muriatic (Acid) | 1-1 | 44 | 63 | 42 |
| Detergent & Muriatic | 2-1 | 47 | 56 | 44 |
| Detergent & SP-3 | 9-1 | 50 | 56 | 45 |
| SP-3 | 9-1 | 51 | 56 | 45 |
| Muriatic | 2-1 | 49 | 59 | 48 |

^a SP-3 is a diluted hydrofluoric acid sold by Slip-Pruf and advertised as a pavement deslicking material. The manufacturers recommend that one pint of acid be mixed with nine pints of water.

As may be seen from the table, a relatively strong solution of SP-3 or muriatic acid improved the skid number substantially, by 17 and 19 skid numbers respectively. However, any gain in skid resistance was lost in six months.

Overlays

Fourteen states and the California Division of Bay Toll Crossing reported using overlays as a method of restoring acceptable skid resistance to concrete pavements. Most concrete pavements are covered by bituminous overlays when they become structurally unsound but the overlays here referred to are for texturing purposes. In some few pieces of correspondence it was difficult to determine if the overlays were for purposes of texturing or strengthening the structure but every attempt has been made to discern between the two and report only on those for texturing.

Arizona

At the time of the canvass (March 1973) Arizona was preparing to place an experimental test section using a thin ($\frac{1}{2}$ "- $\frac{3}{4}$ ") open-graded asphaltic concrete finishing course flushed with (a) latex-emulsion (b) hot asphalt-reclaimed rubber. Thin overlays of Petromat and fiberglass were to be placed over full pavement sections and over joints and/or cracks. Small test patches of open-graded asphaltic concrete flushed with either latex-emulsion or hot rubber-asphalt had indicated that these treatments might be successful.

California (Division of Bay Toll Crossing)

In 1963 and 1964 the San Francisco-Oakland Bay Bridge surface (reinforced concrete) was overlaid with a coal tar epoxy-silica sand mixture. This surfacing had a thickness of about 3/16" that sealed the concrete and provided a good riding surface for several years. Through the years aggregate was lost and eventually remedial action became necessary. Several methods for improving the skid resistance were investigated, and it was decided to use a $\frac{1}{2}$ inch thick epoxy-asphalt, open-graded overlay that could be applied to large areas with a minimum of traffic interference. In November 1969, two test areas totaling 155,000 square feet were resurfaced. One-quarter inch gradings of granite and air-cooled blast furnace slag are being compared in the test. The overlays appear to be doing a good job of providing increased skid and hydroplaning resistance without adding excessively to the dead load. The performance to date indicates good prospects for a long lasting service life and that the overlay is suitable for application to the rest of the bridge.

Illinois

The state of Illinois has used a number of different overlays on portland cement concrete pavements. Of the sand asphalt mixtures, a natural sand-asphalt mix was used on an urban street and was found acceptable (skid number above 36); a trap rock/rubber mixture was used at a rural intersection and was adjudged marginal (skid number 30-36)

and wet bottom boiler slag was used on both an urban street and a rural intersection and adjudged marginal. For the bituminous concrete binder and surface course types, a mix containing a 50% synopal coarse aggregate used on a rural highway gave an acceptable skid resistance. On an urban expressway, with the same accumulated volume, the same mix produced only marginal skid resistance. A 25% synopal mix on a rural highway produced marginal skid resistance; and ramflex, a mixture of crushed gravel and rubber, was placed on an urban street and produced marginal skid resistance. Finally it was found that Illinois's Class I bituminous mixes were unacceptable (skid number below 30) when asbestos or stone sand was used as an aggregate. The test site for these two mixes was an urban expressway. (11)

Kentucky

In the summer of 1972 the Kentucky Department of Highways placed experimental sections of a skid resistant surface treatment called "spray grip" on the Kentucky Turnpike. The binder of the mix was a chemically curing asphalt - extended, two component epoxy compound. The components were heated, measured in proper proportions, and homogenized just prior to being sprayed onto the pavements. The cover aggregate was calcined bauxite. It was calcined at 1,600° centigrade, had a MOHS hardness of eight or higher, and was 86% aluminum oxide (Al_2O_3). The aggregate was sized between a number 7 and a number 16 sieve. A Tennant machine was used for roughening the concrete surface and about three to four pounds of binder to the square yard was applied with a specially designed distributor. After a waiting period of from five to ten minutes approximately 15 pounds of aggregate per square yard was spread on the binder. The surface was generally cured from four to five hours before traffic was allowed on it. About 24 hours were required to effect a complete set of the material. (12) Four months after application, skid tests were performed using a skid test trailer traveling at 40 mph. The average skid number was 75 with a range in values between 70 and 81. Skid resistance was, therefore, very high. The average daily traffic of the highway is about 20,000 vehicles. Performance monitoring of the highway is continuing.

Louisiana

The state of Louisiana placed 11 experimental thin, nonstructural bituminous overlays to establish surface courses that would possess good skid resistant qualities as well as being both economical and durable. These test sections included four different types of bituminous mixtures, such as, asphaltic concrete, sand asphalt, plant mix seals, and slurry seal. The aggregates used in these test sections were crushed gravel, slag, expanded clay, and granite. The evaluation was based primarily on the skid resistant qualities of the mixtures with some consideration being given to the ease of construction and finished riding surface. Skid resistance values were obtained on each of the test sections at approximately four month intervals up to eleven months after completion. In general, the plant mix seals proved to be the best performing of the different mixtures. The slag and expanded clay plant mix seals gave higher skid numbers than did the crushed gravel. The expanded clay slurry seal and Kentucky sand asphalt also resulted in high skid numbers. Of the asphaltic concrete mixtures the expanded clay hot mix showed the highest skid number after eleven months of traffic. (13)

Michigan

The only rehabilitation of old pavements reported by Michigan was by application of a nonskid surface treatment consisting of a distributor applied asphalt into which stone chips with a top size of 3/8" were embedded.

New York

Thin bituminous overlays have been placed over concrete pavements in quite a few locations in New York. Their experience with those overlays has not been good as a general rule. There have been considerable reflective cracking and deterioration of the overlays in the areas over the joints. Sections of the overlay also break loose from the underlying concrete to cause numerous shallow pot holes. In 1971 New York placed a series of overlays on an expressway near Binghamton. These overlays ranged from 1,500 to 2,000 feet in length, with thicknesses varying from 3/4" to 2". At the time of the canvass all test sections were in good condition after being in place nearly two years. The New York respondents attributed part of this success to a new asphalt emulsion tack coat applied to the concrete before placing the overlay. A special emulsion was used instead of the conventional asphalt for the 3/4" sand mix overlay. The bituminous overlays containing emulsions are denser and look better than those containing straight asphalt. Skid test readings on all overlay sections are much higher than those that were taken on the underlying concrete pavements.

North Carolina

Spray grip (see Kentucky summary) has been placed at two locations in North Carolina but no conclusions concerning its effectiveness have been reached.

Ohio

Seal coats and overlays have been used successfully in improving the skid resistance of concrete pavements in Ohio. Especially effective over the years has been a seal coat using No. 8 size slag coarse aggregate and cut-back asphalt emulsion with additives to aid in coating and bonding. Such applications have been thoroughly cured before opening to traffic. An early application provided satisfactory performance for approximately 15 years on a primary route highway before suffering erosion of material from the wheel track area of the outside lane of a four-lane divided roadway. A more recent application on a heavily traveled interstate route has developed spotty erosion areas in the wheel tracks of the outer lane after about five years of satisfactory performance. Studded tire usage in recent years is a factor in the reduced life of the latter installation. The standard asphalt concrete surface course used in surfaces of flexible pavements and for overlays of both rigid and flexible pavements has exhibited good quality skid resistance. It is the opinion of many of their staff that this surfacing material provides the most practical means of correcting pavements deficient in skid resistance. The skid numbers determined for this material are comparable to or exceed those obtained for sand-asphalt mixtures, new concrete, and seal coats. Further experiments with plant mixed seal coats were planned for the summer of 1973.

Oregon

An overlay consisting of a thin coating of grit embedded in epoxy was placed for skid resistance purposes in Portland but was not considered successful. The overlay was probably placed in the late summer of 1972 and inspection around March 1, 1973, showed approximately 35% of the overlay completely gone, either in large sections or in small areas the size of a quarter or larger. Of the 65% remaining, a conservative estimate is that over half of the material had lost its adhesion and was remaining in place due to cohesion with adjoining material.

Rhode Island

In Rhode Island an installation of open-graded plant mix seal was placed on a curved section in 1972. Although no conclusive data on the performance of this mix have been gathered, they state that the mix is performing as intended, which is to help prevent skidding and/or hydroplaning due to faulty geometrics on a curve during wet weather.

Utah

Utah specifications recommend that a slag aggregate be used in overlays to increase the skid resistance of pavements.

Washington

In Washington two overlay systems are used to restore texture. One is spray grip and the other is an epoxy asphalt concrete system. A 3/4" thick overlay of the epoxy was placed on a bridge deck. At the time of the canvass these two systems were not yet a year old, and while they were successful initially, their durability had not yet been proven.

Wisconsin

After studded tires had destroyed longitudinal grooves on a section of curved roadway the state of Wisconsin decided to overlay the curve with bituminous material. A special traprock aggregate was used to resist wear from studded tires. No data or results have been obtained regarding the evaluation of the installation.

Other Methods

Three states have reported using methods of texturing concrete pavements that do not fit into the three categories given above. Summaries of these methods are presented below.

Bush Hammer

Iowa has performed experiments with pneumatic bush hammer treatments using a McDonald Scabbler, which is a multi-head, pneumatically operated unit. The treatment causes numerous surface pits and fractures ranging to a maximum depth of approximately

1/8". This procedure appears to hold strong possibility for restoring significant texture depth, which is an important factor in wet weather skid accident prevention.

In the spring of 1973 in Virginia a 1/4-mile section of I-95 was bush hammered with a Klarcrete machine to determine if skid resistance could be raised by this process. This is a process by which the top layer of concrete is removed to expose the underlying coarse aggregate. Extensive skid tests were performed on the experimental section and the results showed that a substantial improvement in skid resistance was realized in the traffic lane under wet conditions. The greatest improvement in skid resistance was realized with a bald tire in the traffic lane, where an increase of 11 skid numbers at 30 mph with a water film thickness of .020" was significant. With greater speeds or water film thicknesses the increase was even larger. (14)

Pavement Burner Treatment

Iowa has also experimented with a burner treatment. This method causes thin surface spalls the size and depth of which can be regulated by the amount and time of heat application. The burner treatment was accomplished with a homemade L-P gas fired unit used routinely for heating and reshaping asphalt pavements. It has been concluded that the procedure holds strong possibility for restoring significant texture depth to old, slick concrete pavements.

Scarifying With Bulldozer

The West Virginia Turnpike Commission roughed up some areas of portland cement concrete pavement by welding small tips of reinforcing bars to the tracks of a bulldozer and walking it across the pavement in areas with a high incidence of wet-pavement accidents. It is too early to evaluate the results of this process.

COMMENTS FROM STATES USING NO REHABILITATIVE MEASURES

Of the states that replied to the request for information, thirteen had not taken any measure to rehabilitate old concrete pavements for skid resistance purposes. The following are excerpts from the responses from those states.

Our portland cement concrete pavements have not become slippery even though in some cases we have used limestone as the coarse aggregate. We believe that the good skid resistance is due to the amount of mortar brought to the surface by our finishing operations and by use of a clean, coarse, silica sand in the design mix.

We are, apparently, blessed with not having the problem. You are, no doubt, aware of the relatively soft limestones in _____, which have a tendency toward wearing rather than polishing. For this reason, we have no program toward reducing slipperiness on concrete pavements.

The Department of Highways has not rehabilitated any old concrete pavements to reduce slipperiness. The deterioration of the pavements due to studded tire wear and road salts leaves the surface in a very rough condition.

We have very little concrete pavement within the state. As a result we have not done any work in restoring the texture on the pavement. However, we would be interested in your findings since we have built approximately fifty miles of four lane concrete pavement in the last few years and it appears now that we will need some action to restore the texture on these pavements in time.

Other typical responses from those states that had not rehabilitated their pavements for slipperiness were:

All of our portland cement pavements are fairly new and we have not been faced with the problem.

Most of our pavements are asphalt.

We are a rural state with little traffic volume and therefore have not been faced with the problem but anticipate problems at some future date.

Some states simply answered that they had not rehabilitated any of their old concrete pavements.

SUMMARY OF FINDINGS

Grooving

Of the states responding to the request for information, the largest number (19) reported using grooving. From a review of their comments it is apparent that longitudinal grooving does a good job in reducing wet weather accidents, although the skid resistance as measured in the conventional manner does not increase significantly. The mechanisms that appear to help prevent accidents are: (1) vehicles tend to track in line with the grooves and this reduces skidding, and (2) the grooves provide an escape for water under pressure at the pavement/tire interface, and this reduces hydroplaning. Why a vehicle tracks in the grooves is not well understood, although one theory holds that the tire surface deforms to the degree that it protrudes down into the grooves. Most grooving configurations ranged from .095" to 1/4" in width, 1/8" to 1/4" in depth, and had center to center spacings of from 1/2" to 1 1/2". The most commonly used patterns are groove widths of either 1/8" or .095" with a depth of 1/8" or 3/16". Of the grooving patterns now used the one that appears to be best is one employing a groove width of .095", a depth of either 1/8" or 3/16", and a spacing of 3/4" on centers. The .095" groove width tends to cause less trouble for motorcycles and small cars.

Several states have recorded rather astounding reductions in accidents (Wisconsin to cite one) by grooving. In fact, the evidence is so strong from almost all the respondents that it can be said that in most cases longitudinal grooving reduces the number and severity of wet weather accidents significantly. On the negative side, and with evidence perhaps as strong, is the destruction of grooves by studded tires. All states in which studded tires are used extensively reported that grooves are destroyed in a relatively short time. For this reason, a state planning to groove pavements should ascertain the extent of usage of studded tires and take this factor into due account.

Acid Etches

The several states that have used acid etching as a means of increasing the harshness of texture on old concrete pavement are not in complete agreement as to the effectiveness of the method; nor are they in agreement as to the optimum strength and type of acid to be used. The author believes that the evidence indicates acid etching to be a good method for temporarily deslicking concrete pavements. Immediately after application the skid number may increase as much as 20, but within a period of six months the pavement is back to its before treatment level. It also appears that acids do as good a job in a one to one water/acid ratio as they do in stronger solutions. The acids most often used are hydrochloric and hydrofluoric.

Acid treatments have the disadvantages of being dangerous to apply and requiring extensive protective clothing for personnel making the applications. The acids also present a pollution problem and are strong enough to remove or damage automotive paints if not neutralized. These factors limit the attractiveness of acid etching.

Overlays

For an overlay to be successful it must meet at least two criteria. First, it must adhere to the underlying concrete without cracking or sloughing off, and secondly it must produce the desired skid resistance.

States using thin, nonstructural bituminous overlays have run into serious problems in that considerable reflective cracking and deterioration of the overlays have occurred in the areas over the joints. However, some of the more recent overlays using special asphalt emulsion tack coats applied to the underlying concrete have been reported to be successful.

Other overlays employing epoxies as cementing materials appear to be holding up well. Spray grip used with a calcined bauxite aggregate has been applied in several places and preliminary reports on performance have been good. Epoxy asphalt open-graded overlays have been used successfully in high volume locations such as the San Francisco-Oakland Bay Bridge. Seal coats using slag coarse aggregate and cut back asphalt emulsion with additives to aid in coating and bonding have been used successfully in Ohio. Refer to Table 2 for the different overlays and assessments of their performance.

Other Methods

There has been limited usage of three other methods to increase the harshness of old concrete pavements. Bush hammering has been employed by two states on experimental test sites and the results have been favorable. This method, which exposes the coarse aggregate to become the new riding surface and also leaves the exposed aggregate in a highly fractured, sharp-edged condition slightly raised above the surrounding mortar, may be a better method than grooving in northern states where studded tires destroy the grooves so quickly.

The pavement burner treatment has been used by one state and the conclusion is that this method holds strong possibility for restoring significant texture depth to old, slick concrete pavements. This restoration is accomplished by thin surface spalling, the size and depth of which can be regulated by the temperature and length of heat application.

In one state small tips of reinforcing bars were welded to the tracks of a bulldozer and it was walked across the pavement to rough it up. Evaluation of this method had not been performed at the time of the canvass. Table 2 lists the states that rehabilitate their old concrete pavements for slipperiness, the type(s) of treatment used and, where available, an assessment of the treatment.

Table 2

Summary of the Use of Methods of Rehabilitating Old Concrete Pavements

| State | Type(s) of Treatment | Assessment or Commer |
|-----------------------------------|---|---|
| Arizona | Overlay — Open-graded asphalt flushed with latex emulsion or hot asphalt-reclaimed rubber | |
| California | Grooving — Longitudinal | Successful |
| California (Div. of Bay Tolls) | Overlay — Coal tar epoxy — silica sand Overlay — Epoxy-asphalt, open-graded | Successful Successful |
| Colorado | Grooving — Longitudinal | Not successful due to studded tire wear |
| Connecticut | Grooving — Longitudinal | Successful first year but decreased thereafter because of studs |
| Florida | Grooving — Transverse | Not successful |
| Hawaii | Grooving — Longitudinal | |
| Illinois | Overlay — Natural sand asphalt mix (urban street) | Successful |
| | Overlay — Traprock/rubber mixture (rural intersection) | Marginal |
| | Overlay — Slag asphalt (urban st., rural int.) | Marginal |
| | Overlay — Bituminous concrete with 50% synopal coarse aggregate (rural highway) | Successful |
| | Overlay — Bituminous concrete with 50% synopal coarse aggregate (urban expressway) | Marginal |
| | Overlay — Bituminous concrete with a 25% synopal coarse aggregate (rural highway) | Marginal |
| | Overlay — Ramflex, a mixture of crushed gravel and rubber (urban street) | Marginal |
| | Overlay — Bituminous concrete with stone sand or asbestos | Not successful |

Table 2 (cont.)

| State | Type(s) of Treatment | Assessment or Comment |
|-------------------|---|-------------------------------------|
| Iowa | Bush hammer — removal of pavement surface | Holds strong possibility |
| | Pavement burner treatment | Holds strong possibility |
| Kentucky | Overlay — Spray grip | Successful |
| Louisiana | Grooving — Transverse | Not successful |
| | Overlay — Plant mix seals | Successful |
| | Overlay — Expanded clay asphaltic concrete | Successful |
| | Acid etching — SP 3 | Successful as temporary solution |
| Maryland | Grooving — Longitudinal and transverse | |
| Michigan | Overlay — Chip seal 1/8" thick | |
| Nebraska | Grooving — Longitudinal | Not successful |
| New Jersey | Grooving — Longitudinal | |
| New York | Grooving — Longitudinal | Successful |
| | Acid etching | Successful as temporary solution |
| | Overlay — 1971 bituminous overlays using a special emulsion | Successful |
| Thruway Authority | Acid etching | Successful as temporary solution |
| North Carolina | Grooving — Longitudinal | Successful |
| | Overlay — Spray grip | |
| | Acid etching | |
| Ohio | Grooving — Longitudinal | Successful until destroyed by studs |
| | Acid etching | Successful as temporary solution |
| | Overlays — Seal coats | Successful |
| | Overlays — Bituminous concrete surface courses | Successful |

Table 2 (cont.)

| State | Type(s) of Treatment | Assessment or Comment |
|---------------|--|--|
| Oregon | Grooving — Longitudinal | Successful |
| | Overlay — grit embedded in epoxy | Not successful |
| Pennsylvania | Grooving — Longitudinal | Successful |
| Rhode Island | Overlay — Open-graded bituminous plant mix | Successful |
| Texas | Grooving — Longitudinal | Successful |
| | Acid etching — SP-3 | Not successful |
| Utah | Overlay — Specifications say slag aggregate to be used | |
| Virginia | Grooving — Longitudinal | Successful |
| | Acid etching | Successful as temporary measure for 6 months or less |
| | Bush hammering | Successful |
| Washington | Grooving — Longitudinal | Successful |
| | Overlay — Spray grip | Initial Success |
| | Overlay — Epoxy-asphalt system | Initial Success |
| West Virginia | Grooving — Longitudinal | |
| Wisconsin | Grooving — Longitudinal | Very successful until worn by studded tires |
| | Overlay — Bituminous overlay using traprock aggregate | |

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