INVESTIGATION OF ACCIDENT REDUCTION BY GROOVED CONCRETE PAVEMENT

Final Report

by

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ABSTRACT

This report is a category 2 experimental project evaluation written in conjunction with EHS-I-10-3(93)158 and EHS-I-12-1(44)0 contracted to groove hardened PCC pavement. In it the wear characteristics, pavement texture, skid resistance, and the accident reduction are discussed, plus the experience Louisiana had with the sawing of the grooves in its hard-gravel portland cement concrete.

The results of the study indicated that (1) because of the grooves the texture measurements went up and did not change substantially throughout the study period; (2) the grooves showed signs of wearing out in spots but an average wear was 0.006-0.009 inches per year, so that the projected time to "wear out" is 9 to 18 years on this project; (3) skid resistance rose from a skid number of 32 before grooving to 48 near the termination of the project; and (4) the wet accident rate was reduced some 64% near the end of the study.

IMPLEMENTATION

Although other surface corrective systems are available for correction of skid resistance and/or hydroplaning problems, grooving is indicated as a viable alternate for consideration for correction of hydroplaning principally, with some secondary benefits of skid resistance.

Specifications are available for the Department's use whenever grooving can or should be considered as a surface safety treatment.

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INTRODUCTION

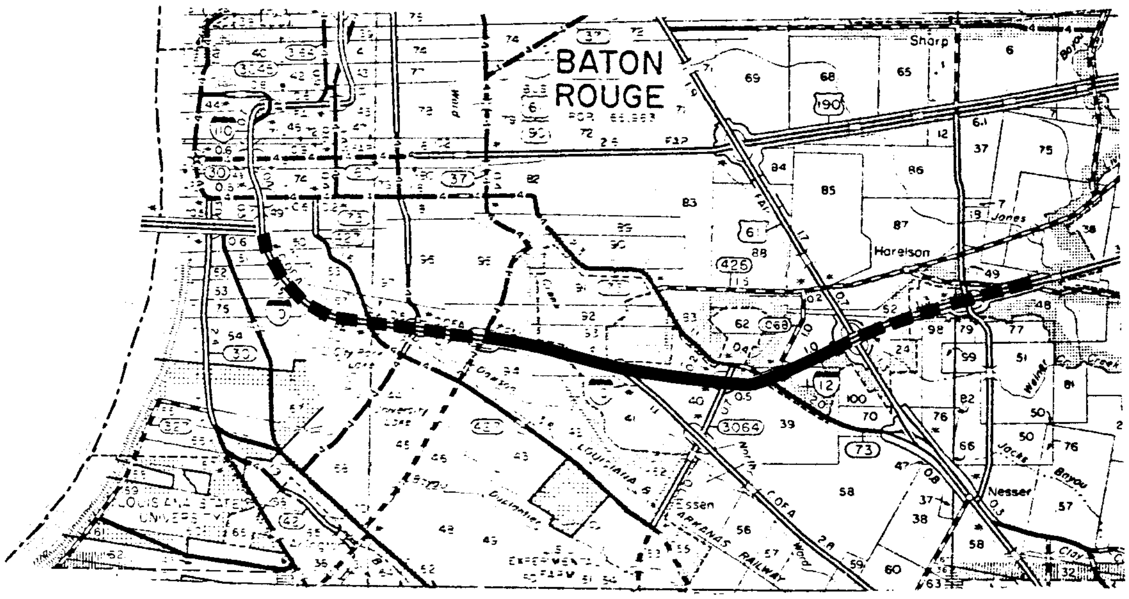
Grooving hardened concrete pavement by sawing with a circular diamond-imbedded saw is not a new technique. For instance, the author did a study back in 1967 on grooving, but in that case the grooving was done mainly to improve the skid resistance of slippery locations and provide drainage as a secondary feature. The grooves were transverse and "V" shaped. In this study the grooves are square-cut and longitudinal to the traffic to reduce hydroplaning. California was among the first states to try this type of grooving back in the early sixties, but it was NASA that was first in the United States to recommend this procedure to airports.

The project was initiated just prior to public demand to do something about a section of I-10/I-12 in Baton Rouge that seemed to be the site of an inordinate number of single-vehicle wet-weather accidents. During a particularly intense period of summer thunder showers, there were as many as 16 luminaires downed out of 141 along this section.

This then is the report of the results of a research project that was done in conjunction with a Category 2 experimental project, EHS-I-10-3(93)158 and EHS-1-12(41)0, to evaluate the effectiveness of grooves in reducing accidents and the wear characteristics of grooves in hardened concrete.

Background Research

Early in September, 1970, the researchers looked into the problems with I-10/I-12 that were causing the high incidence of accidents that were evident by the downed light standards on this particular stretch of interstate. The section of I-10 immediately to the west (an older roadway) and of I-12 immediately to the east (a younger one) didn't seem to be having the same trouble as the section investigated (Figure 1). The skid resistance of that section and two sections on either end (indicated by a dashed line on the figure) were investigated together. Figure 2 and Table 1 present the results of that investigation.

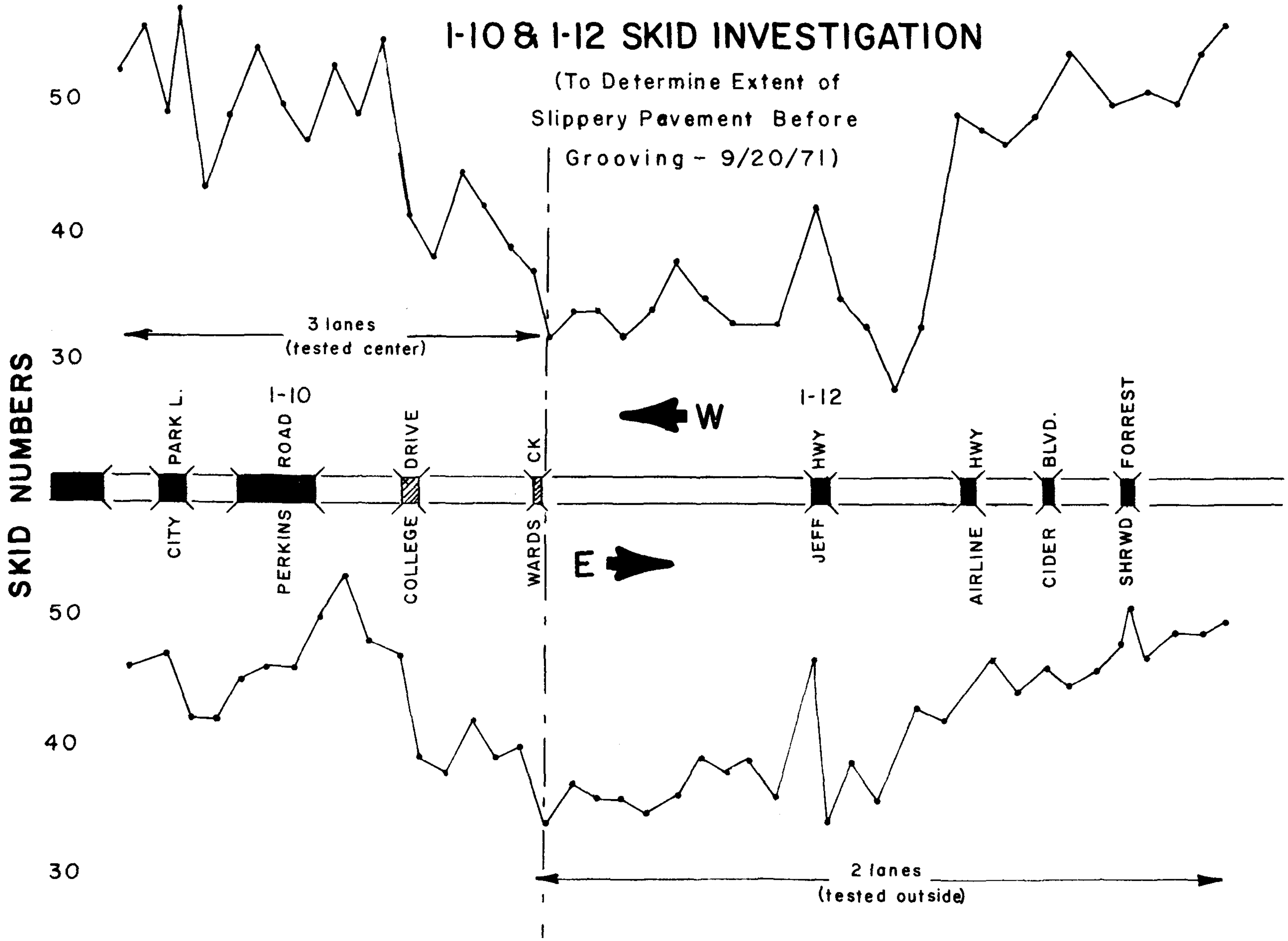


Vicinity Map

Figure 1

To the Research and Development Section this seemed an ideal project to try the grooving that had been successful in California on some of their freeways in Los Angeles. "Grooving" is the process of sawing shallow, square, uniformly spaced grooves in pavements. They can be either transverse or longitudinal. Transverse grooving is used to prevent water puddling by draining it to the shoulder of the road and perhaps offer some skid resistance for a period of time. Longitudinally cut grooves are more effective in directional control of a vehicle and provide an escape route for water from beneath tires. Water buildup under the tires, particularly smooth or worn tires, traveling at speeds in excess of 45 or 50 miles per hour (72.4 or 80.5 km/hr) is the major cause of hydroplaning. Since

Figure 2


I-10 & I-12 SKID INVESTIGATION
(To Determine Extent of
Slippery Pavement Before
Grooving - 9/20/71)
SKID NUMBERS
50
40
30
50
40
30
3 lanes
(tested center)
2 lanes
(tested outside)
I-10
I-12
W
E
CITY
PARK L.
PERKINS
ROAD
COLLEGE
DRIVE
WARDS
CK
JEFF
HWY
AIRLINE
HWY
CIDER
BLVD.
SHRWD
FORREST

there was a preponderance of off-road, single-vehicle accidents, the Department chose the longitudinal grooves. Using Los Angeles specifications as a guide, the Research and Development Section developed the specifications. Essentially, they called for the grooving blades to be 0.095 ± 0.003 inches wide (2.4 ± 0.076 mm) spaced at 3/4-inch (2-cm) centers. The depth of the grooves was specified at 1/4 inch ± 1/16 inch (0.63 ± 0.16 cm). A noise level was specified together with waste (cutting) disposal. This specification is included in the appendix.

TABLE 1

ACCIDENT DATA FOR 1970 ON I-10/I-12 IN BATON ROUGE

LOCATION	TOTAL ACCIDENTS 1970	WET ACCIDENTS 1970	% WET ACCIDENTS	WET ACCIDENT RATE (per MVM)*	WEATHER INFORMATION
MISS. RIVER BDG TO COLLEGE DR.	118	12	10.2	0 .23	RAINED 112 DAYS 1970 OR < 5.0% ON HOURLY BASIS
COLLEGE DR TO AIRLINE HWY	110	32	29.8	0.50	

* MILLION VEHICLE MILES

PURPOSE AND SCOPE

The purpose of the experimental project was to upgrade the safety of I-10/I-12, College Drive to Airline Highway, by reducing the hydroplaning potential and adding raised pavement markers. This was done under State Project Nos. 450-10-42 and 454-01-16, F.A.P. Nos. I-10-3(93)158 and I-12-1(41)0. The purpose of this research project (No. 736-02-14[73-1G(B)]), as was mentioned in the introduction, is to evaluate the wear characteristics of the grooves and their effectiveness in reducing accidents.

It was envisioned at the inception of the research that the evaluation would be accomplished by:

- (a) Visual observations with photographs.
- (b) Skid resistance measurements.
- (c) Texture measurements by:
  1. Sand patch method.
  2. Stereo-photographic method.
  3. Depth of grooves.
- (d) Accident analysis.

The stereo-photographs are very difficult to reproduce, and this is the main reason they will not be discussed in depth in the report. As it turned out, however, they showed very little. What they did for the research will be touched on later. At any rate, the other tests and observations were run every six months. These will be reported. In addition, an accident analysis was run on this project, and this is the most important data of the study.

One other aspect of this study that wasn't in the work plan will be brought out and that is the difficulty the Department and the contractor had with the project. This will be brought out so that any agency who wishes to groove in the future will be aware of problems encountered by the Department,

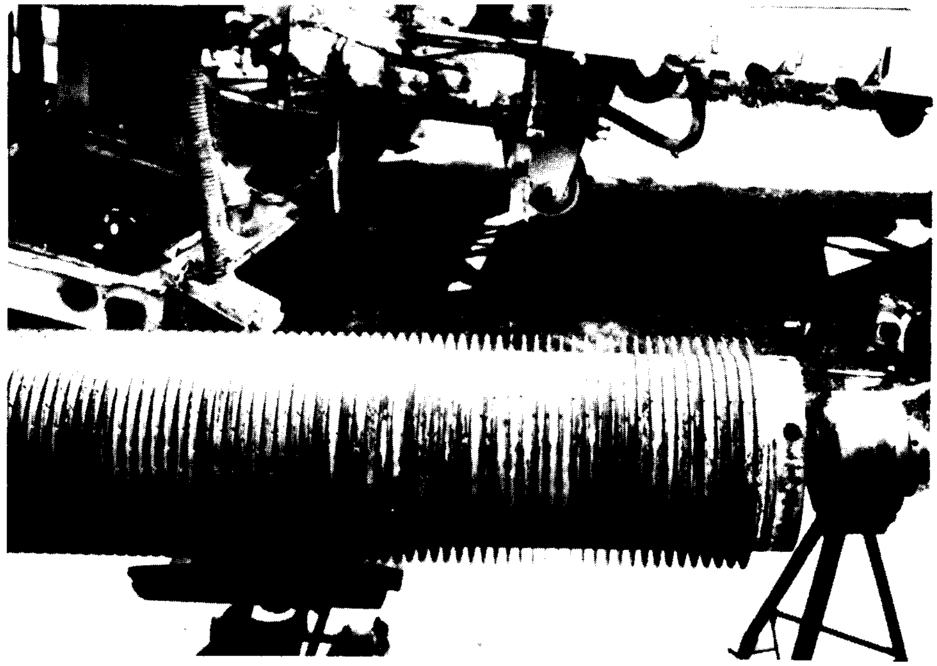
THE GROOVING

Bids

In spite of California's experiences of low cost of grooving per square yard, the Department received estimates of $2.25 a square yard ($\$2.69/m^2$) in September of 1971. Economic consideration forced them to go out for bids for a skid resistant overlay. However, only one bid was received on this type of construction for approximately 30% over the engineering estimate. After rejecting this, the Research and Development Section obtained information that grooving would be more economical; and the Federal Highway Administration approved the Category 2 experimental project in January 1973 for grooving. Bids, which included about $12,000 worth of raised pavement markers as well as 104,000 square yards of grooving, were received in February 1973. The low bid was 13% below the engineering estimate, and the grooving itself ranged from $1.00 to $1.52 per square yard ($\$1.19/m^2$ to $\$1.82/m^2$). The bid price accepted was $1.10 a square yard ($\$1.31/m^2$), $0.15 ($0.18) under the 1973 estimate.

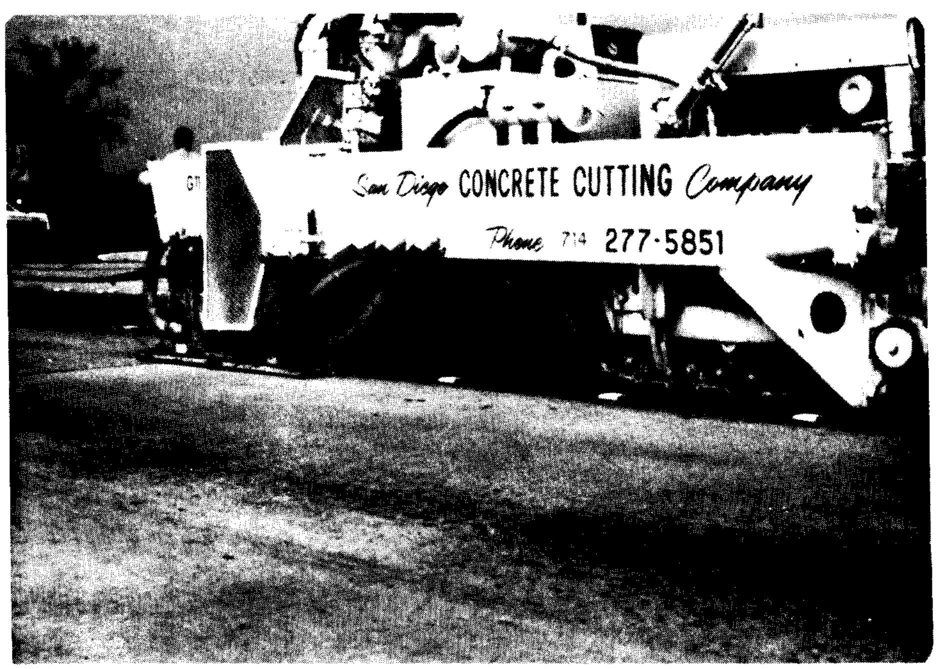
Equipment

Figures 3 through 6 show the equipment that was used. Blades spaced at 3/4 inch (1.90 cm) on centers make up the cutting head (Figure 3). They are propelled forward by a tractor driven by a 270-horsepower (201-kw) diesel engine (Figure 4). A large tank truck is pulled behind the groover and circulates water over the blades for cooling and lubricating (Figure 5). Subsequent to blade lubrication and cooling, the water is vacuumed into the tank along with the residue (cuttings) from the groover by a pump on the truck. The cuttings settle in the tank and the water is recirculated. Consequently, very little residue was left after cutting, and there was no dust to hamper visibility of traffic using the roadway while cutting was in progress. Figure 6 shows the vacuum head behind the blade.



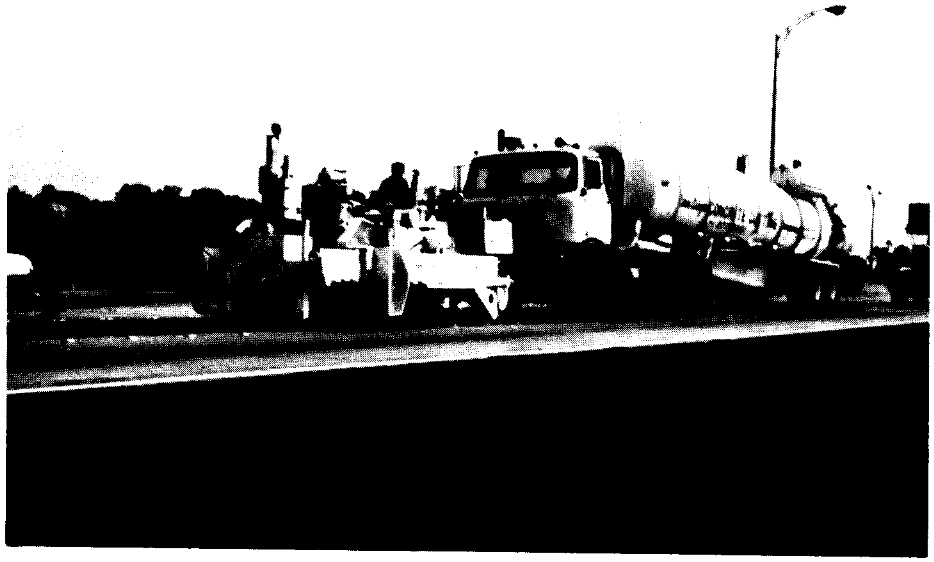
Cutting Head

Figure 3



Grooving Prime Mover (Tractor)

Figure 4



Water Tank

Figure 5

Water Coolant and Vacuum Head

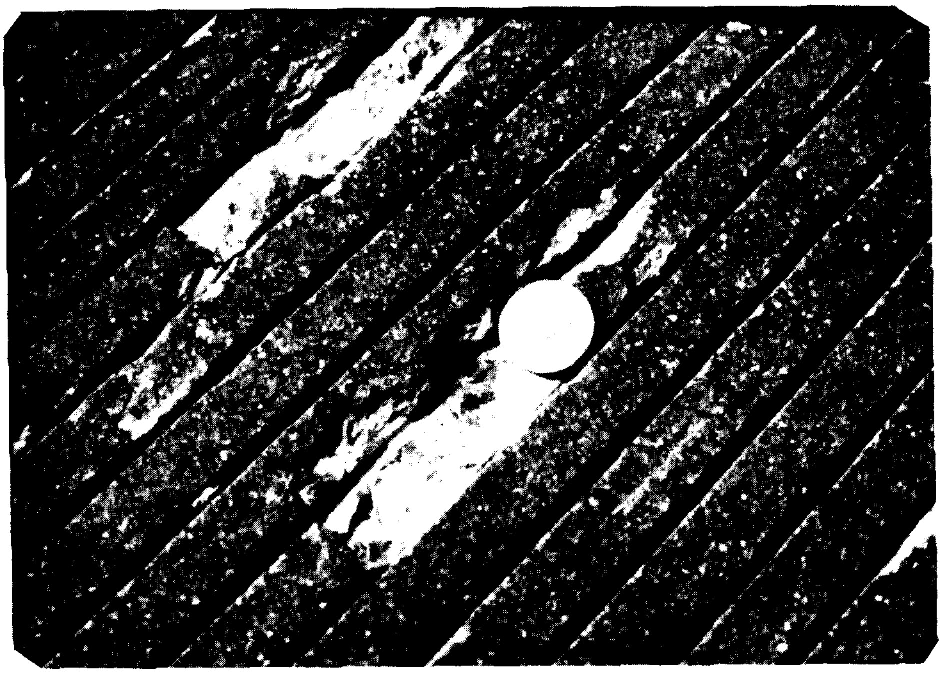
Figure 6

State Project Nos. 450-10-42 and 454-01-16

Grooving on I-10/I-12 was started on April 2, 1973, over two and a half years after the initiation of the idea. Then the contractor had his problems. Three-sixteenth inch (4.7 mm), the minimum depth of cutting, as it turned out, was much harder to maintain than was thought. After the first 100 feet (30.4 m) or so, the shoulders of the grooves began spalling, and the aggregate began breaking rather than being cut. Figures 7 and 8A show the first of the spalled grooves, and the situation kept getting worse (Figure 8B). The contractor changed blades, believing that the problem was with the matrix bonding the diamonds to the cutting edge. With this change he was able to cut the grooves, but at a slower rate--approximately 300 feet/10-hour day (91 m/10-hr. day). Early on the fourth day, the cooling system failed and the blades burned up. With no other blades on hand, the original ones were put back on. When this again produced spalling, the project was shut down.

Spalled Grooves

Figure 7



Close-Up of Spalled Grooves

Figure 8A

Worsening of Spalling

Figure 8B

During several meetings between the contractors, blade manufacturers, Federal Highway Administration, and Louisiana Department of Transportation and Development personnel, it was established that grooving was too deep. The cutting contractor asked, therefore, to reduce the depth of cut from 1/4 to 1/8 ± 1/16 inch (6.3 to 3.15 ± 1.57 mm). They stated that this would not hurt the safety project. The reason California used 1/4-inch (6.3-mm) depth was strictly for wear and that this concrete probably wouldn't wear as fast as the pavement in California since the aggregate was so hard. Reasons given for the failure were two: the 3/16-inch (4.71-mm) cut in hard aggregate developed abnormally high temperatures which fractured the aggregate, and this particular concrete was constructed with insufficient mortar to keep the blades sharp. It was said that the fines are needed to hone the matrix away from the diamonds and keep them from glazing. As a result of the meetings it was agreed to reduce the cut to 1/8 inch (6.3 mm) for a reduction in price to $1.05/square yard ($1.26/m^2).

Grooving was resumed on April 21 and proceeded without further shutdowns until completion on June 15. Cutting was slow but without the spalling. The contractor had expected to travel at the rate of 10 feet/minute (3.05 m/min.) but was cutting only at about 6 feet (1.83 m). The rate seems related to temperature of the concrete. Cutting in the early morning, and even in the shade during the day, seemed faster. Thus, with the desire to finish as close to the estimated time as possible, the contractor requested permission to operate at night. On May 20, with the project only 50% complete, the Department agreed and operations were switched to 8:00 p.m. to 6:00 a.m.

After a few days of cutting, the rate was increased to that which was hoped for--10 feet/minute (3.05 m/min.). The cooler pavement and more efficient blades supplied to the contractor were given as the reasons.

RESEARCH METHODOLOGY

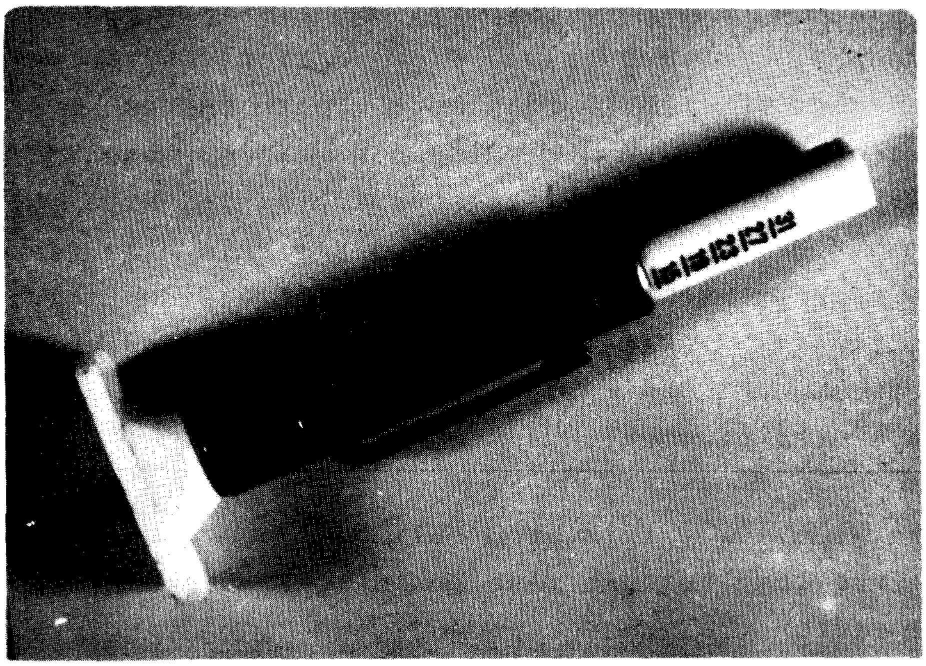
Texture Measurements

Twelve test sites were picked by a random procedure. Before the cutting was started, some sites were moved by recalculation of the random log mile if they fell in the vacinity of a "ramp," overpass, or a curved section. These areas were not selected because they would either present difficulty for those who would have to measure the texture or to the skid measurements. Six sites were spaced randomly in the eastbound roadway, and six were spaced in the westbound roadway, also randomly. Two additional sites were purposely placed in a curve in both roadways. These curves have an adequate sight distance to allow a slowing and merging maneuver for the considerable amount of traffic approaching the site while texture measurements were taken. The reason for this bias placement was that the area was the site of a number of accidents prior to this project. In all, there were 14 test sites marked by a painted square the size of the bottom of the box used to take stereo pictures of the pavement.

While the grooving was in progress, the researchers performed the "before grooving" texture test immediately ahead of the pass of the groover. After the groover passed, the "immediately after" measurements were made. The texture was measured periodically for five years.

Two sand patches were run in the left wheel path at each test site each time the texture measurements were made, and one set of stereo pictures was taken inside the rectangle painted on the pavement each time. These rectangles were repainted periodically in order to retain the sites for testing. To help the skid tester see the locations, a sign indicating the number of the site was located just off the paved shoulder, and the same number was painted on the shoulder. In spite of all this, one of the bias locations was "lost" when maintenance chose to reseal the shoulder obliterating the painted number. The sign was taken down in order to do the resealing, and the painted square was worn off by traffic.

In addition to the patches and photographs, the depth of the grooves was measured with a tread depth gauge used for automobile tires. Figure 9 shows the gauge.



Tire Tread Depth Gauge

Figure 9

Skid Measurements

Skid tests were made at three speeds each time the texture measurements were made except, of course, just prior to grooving and immediately after. The "prior" skid measurements were done several months ahead of the grooving, and the "immediately after" tests were not run until the grooving was complete. These tests were made with a full-scale, locked-wheel skid trailer substantially conforming to ASTM 274, fabricated by the Louisiana Department of Transportation and Development. The dates of the skid tests and texture measurements are given in Table 2, along with the number of days between tests and the cumulative days, on the following page.

Accident Data

The number of accidents was investigated periodically during the course of the study. Every year the Department receives accident data on the highway network of the State from the Highway Safety Commission, and it is stored in the computer. Each individual accident report on the interstate highways is kept on file in the Department's Traffic and Planning Section. These records were used in summarizing the accident data in this report. Three different traffic counts were taken for this study. The average was used to calculate the accident rates (accidents/million vehicle miles).

TABLE 2

TEST DATES AND CUMULATIVE DAYS BETWEEN TESTS

Date	Days Between	Cumulative Days
7-1-73	0	0
10-9-73	100	100
1-18-74	101	201
4-30-74	102	303
7-18-74	79	382
11-20-74	125	507
6-25-75	217	724
1-15-76	204	928
11-18-76	307	1,235
11-17-77	364	1,599
2-23-78	98	1,698

RESEARCH RESULTS

Texture Measurements

The two types of texture measurements to be reported herein are the sand patch and the depth of grooves. As mentioned, stereo photographs do not lend themselves to inclusion because of the nature of the viewing and interpretation. Suffice it to say that they only lent support to the study.

Sand Patches

Sand patches were done in accordance with DOTD TR 617-74, Method of Test for Measurement of Texture Depth by Sand-Patch. This involves spreading a measured volume or weight (1.5 $in.^3$ [24.6 cm^3] or 1.37 oz. [38.83g]) of sand, sieve sized +50-100, into a circular patch such that it fills the surface depressions to the level of the peaks. In other words, it is spread in as near a circle as possible until it will not spread any further, being careful not to create "bald" spots. The spreader is a 2-1/2-inch (63.5-mm) diameter, flat, wooden disc with a 1/16-inch (1.59-mm) hard rubber facing attached to one side and a handle to the other. At least five measurements are made across the patch, and these are averaged and recorded as the diameter. Then the height of this thin sand cylinder is computed from the formula.

$$T.D. = h = \frac{4V}{\pi D^2}$$

Where D = diameter of patch, in.
h = height of patch, in.
T.D. = texture depth, in.
V = volume of sand, $in.^3$

Before discussing the results of this test, a brief commentary of the operator(s) should be given. In general, the same operator was used for these tests except for the test run on July 18, 1974. This trend shows on the results given later. Since this is a subjective test, the discussion of when to stop the spreading almost always comes up, and the operator must get the patch as nearly circular as possible.

In order to show that the subjective variation was held to a minimum, the statistical variation of the main operator was obtained. Three pavements were chosen, one each of coarse, medium, and fine texture. Ten sand patches were run in the same spot on each. The results are given in Table 3.

It can be seen from Table 3 that the variances (σ^2) of the operator were less than 0.02 inch^2 and the standard deviation was less than 0.135 for the three pavement conditions. This figure not only indicates the variability of the operator but also variations in the weights of sand and the variation of the sand itself. The latter is well standardized in that Ottawa sand was used.

Texture Depth

Table 6 in the appendix shows the results obtained from the sand patches run throughout the period of testing. Two numbers separated by a dash and representing the two texture depths (T.D.) taken at either end of the painted rectangle at each location make up an entry. These results are plotted in Figure 10. Figure 10 shows by bar-o-graph the texture depth by site number and date. The figure shows that there was no particular trend toward wearing over the five-year period of study.

TABLE 3

VARIATION IN PATCH RESULTS
(SINGLE OPERATOR)

Coarse Pavement (Asphaltic Concrete Parking Lot)

Test No.	Range of Diameters (In.)	Average Diameter (In.)
1	4.4 - 4.6	4.46
2	4.3 - 4.7	4.46
3	4.4 - 4.7	4.48
4	4.3 - 4.7	4.46
5	4.2 - 4.7	4.46
6	4.2 - 4.5	4.36
7	4.2 - 5.0	4.44
8	4.2 - 4.8	4.46
9	4.2 - 4.6	4.36
10	4.3 - 4.8	4.50

$\sigma^2 = 0.002$ $\sigma = 0.047$

Medium Pavement (Asphaltic Concrete Parking Lot)

Test No.	Range of Diameters (In.)	Average Diameter (In.)
1	7.2 - 7.8	7.50
2	7.4 - 7.6	7.44
3	7.4 - 8.0	7.84
4	7.4 - 7.6	7.58
5	7.7 - 7.8	7.72
6	7.7 - 7.9	7.82
7	7.5 - 8.1	7.76
8	7.4 - 8.1	7.76
9	7.5 - 8.0	7.68
10	7.6 - 7.8	7.70

$\sigma^2 = 0.018$ $\sigma = 0.134$

Fine Pavement (Concrete Sidewalk)

Test No.	Range of Diameters (In.)	Average Diameter (In.)
1	9.3 - 10.3	9.64
2	9.0 - 9.5	9.30
3	9.5 - 9.8	9.70
4	9.2 - 9.8	9.46
5	9.2 - 9.6	9.46
6	9.3 - 9.6	9.42
7	9.3 - 9.8	9.50
8	9.4 - 9.8	9.54
9	9.3 - 9.9	9.60
10	9.1 - 9.32	9.32

$\sigma^2 = 0.017$ $\sigma = 0.130$

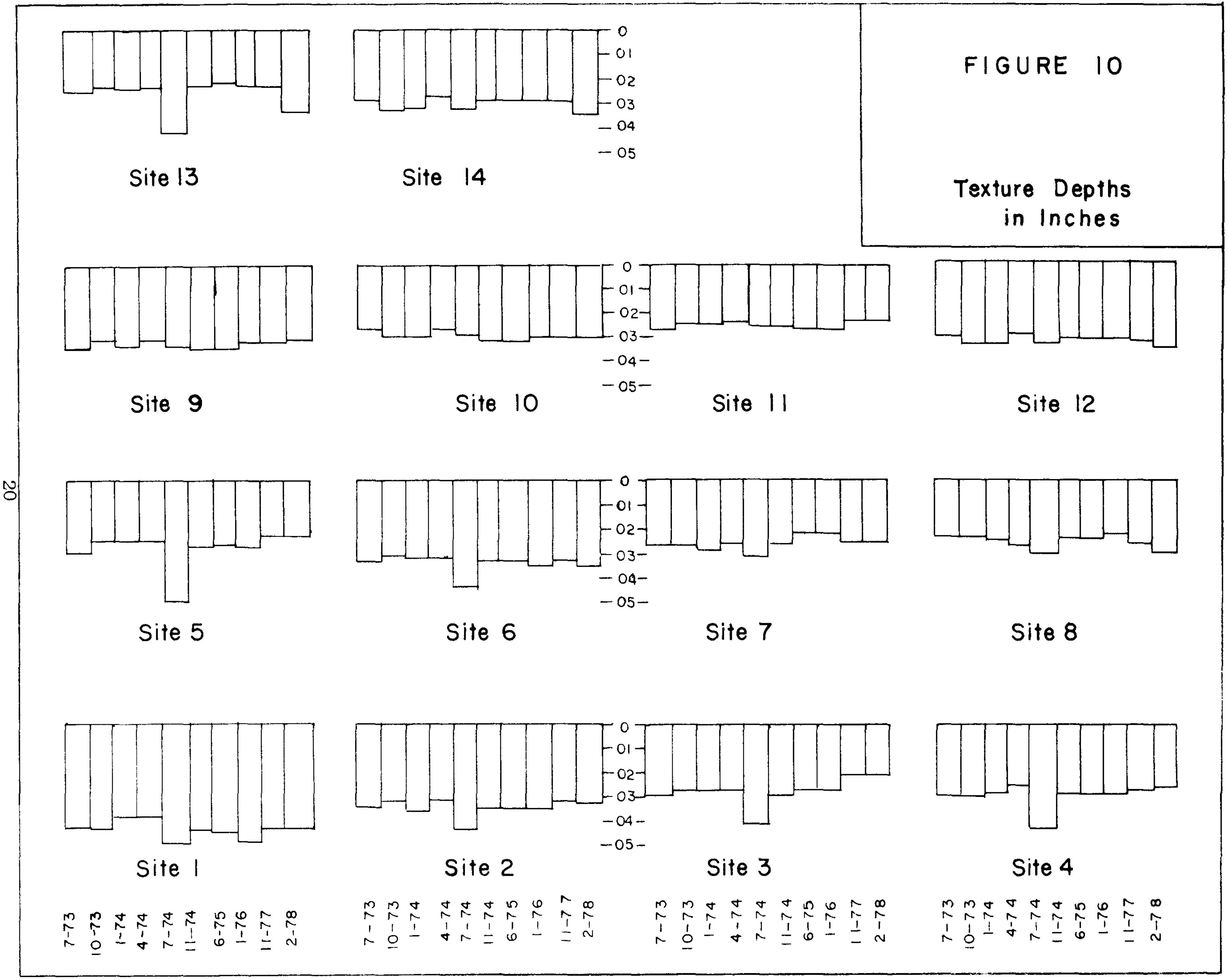


FIGURE 10

Texture Depths in Inches

Two phenomena are rather clear, however. On July 18, 1974, a different operator was used on the westbound roadway, sites numbers 1 through 6 and 13, but the regular operator took over for the rest. Consequently, the texture depths are greater for sites 1 through 6 and 13 on that date (Figure 10). The second can also be seen on Figure 10. The fact that site 1 was in the section that was grooved to a depth of 1/4 ± 1/16 inch (6.73 ± 1.59 mm) shows up as having slightly more of a texture depth than the others. The fact that site 1 has deeper grooves is emphasized by the figures illustrating groove depth in the next section.

Some word must be said relative to the lack of texture degradation with age. It should be remembered that this highway had very little texture prior to grooving, causing the hydroplaning mentioned in the introduction. The checks of the sites before grooving revealed that they had a texture depth of from > 0.013 to 0.014 inches (> 0.33 to 0.35 mm), which is a very slight amount. Therefore, the degradation of little or no surface texture is lacking in practical significance, and the fact that the texture depth as measured by the sand patch after grooving varies from 0.05 to 0.02 inches (1.27 to 0.51 mm) comes from the grooves. In other words, the grooving of a smooth surface does not make that surface rough; it merely puts grooves in it.

Depth of Grooves

The depth of the grooves was measured at each testing date with a tire tread depth gauge (Figure 9) which is graduated in 32nds of an inch (0.794 mm). Table 7 in the appendix shows the results in inches. Figure 11 shows the results plotted as a bar-o-graph. Figure 12 shows the wear of selected sites. In Figure 11 the bars represent the depths from some standard reference plane even though that is not the way the wearing occurred, i.e., the grooves wear from the top down. However, since no reference plane could be established to within 1/32 inch, the depths were depicted as though

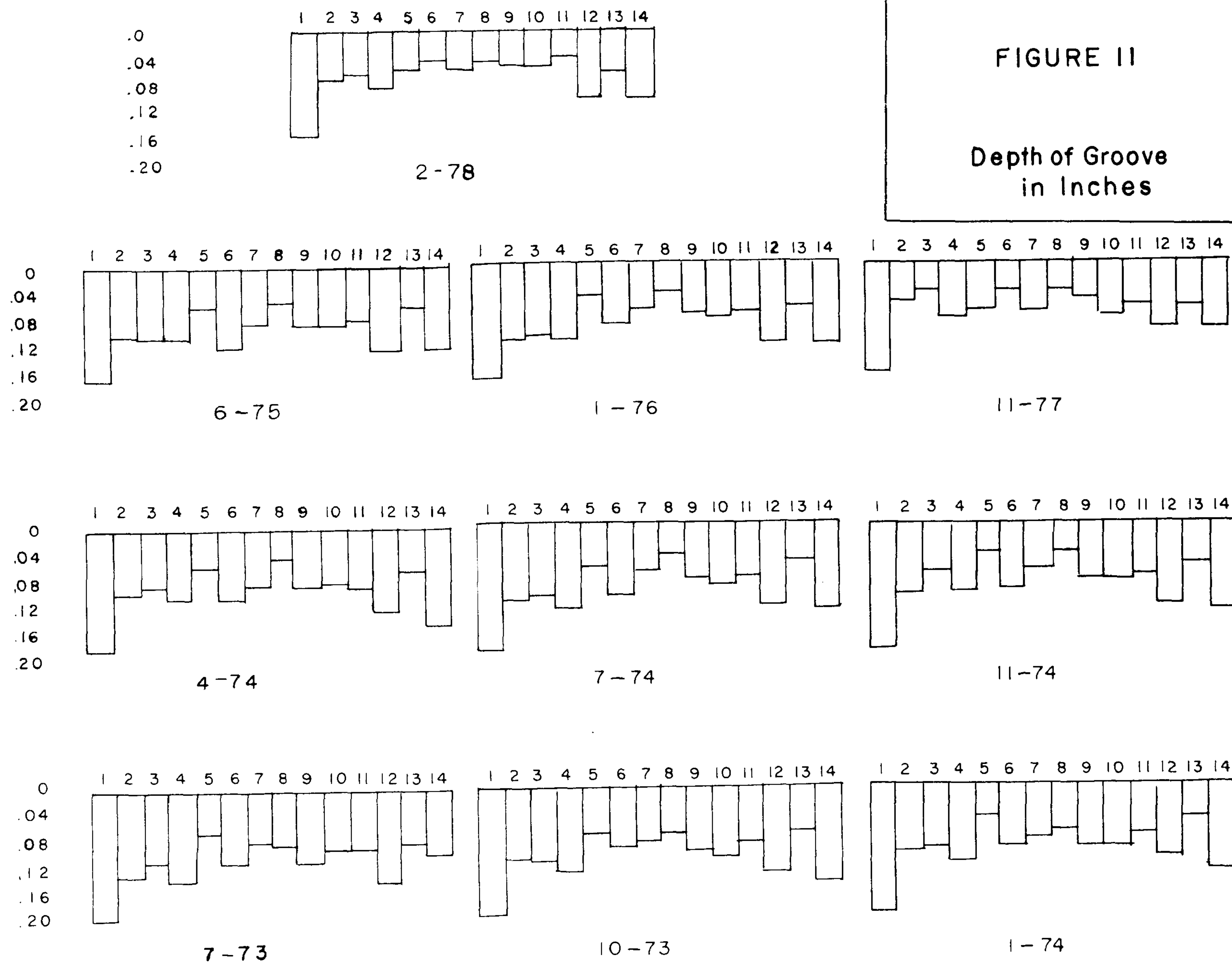


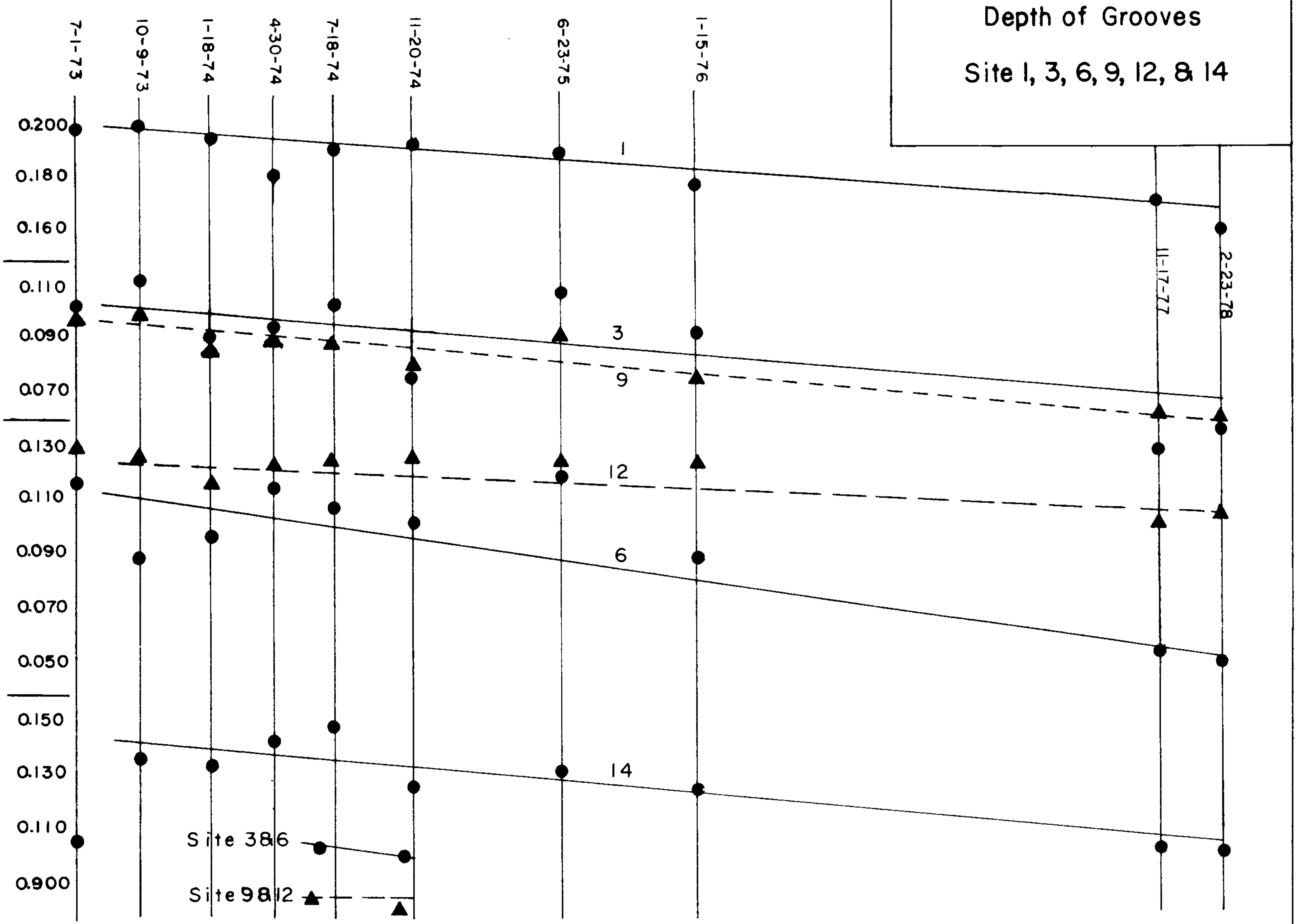
FIGURE II

Depth of Groove in Inches

FIGURE 12

Depth of Grooves

Site 1, 3, 6, 9, 12, & 14



the tops were at an arbitrary plane, and the grooves were shortened from the bottom. As can be seen, the depths at site 1 where the grooves were cut deeper show as a longer bar. At sites 12 and 14 the grooves are also deeper, but this is unexplained.

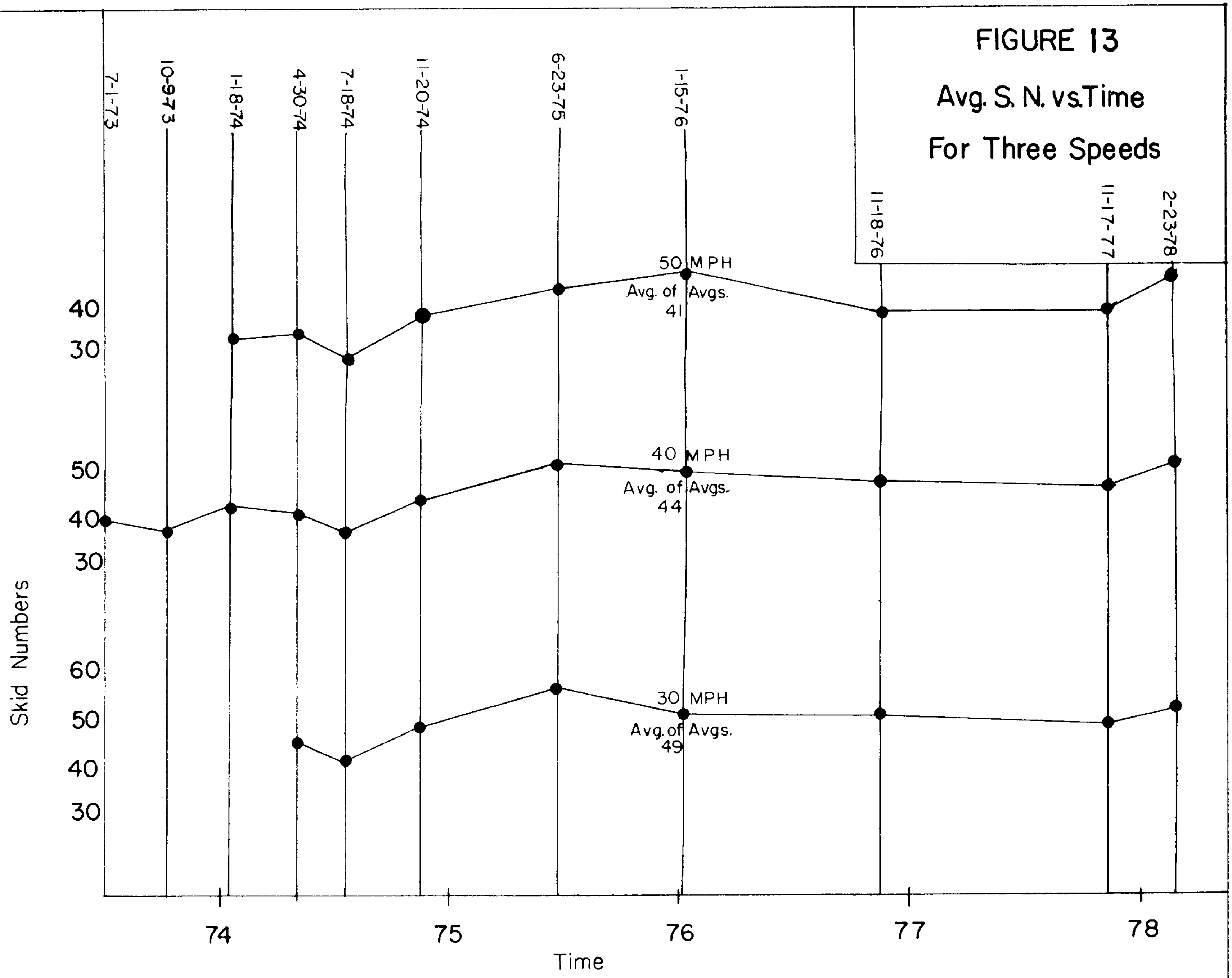
Figure 12 shows the wear rates of six sites picked at random to represent the entire grooved section. Four of the random sites exhibit essentially the same wear rate of 0.007 inches/year (0.178 mm/yr) (i.e., 1, 3, 9 and 14), while site 12 has approximately 0.004 and site 6 has 0.015 inches/year (0.102 and 0.381 mm/yr). The wear rates range between 0.003 and 0.015 inches/year (0.076 and 0.381 mm/yr) with an average of 0.007 inches/year (0.178 mm/yr). At that average the grooves should last approximately 9 to 18 years at the grooving depth of 1/8 ± 1/16 inch (3.2 mm ± 1.6 mm).

Skid Resistance

Tables 8 through 10 in the appendix show the results of the skid tests at 30, 40 and 50 miles per hour (48.27, 64.36, 80.45 km/hr) taken on the sites throughout the period of evaluation. Figure 13 averages all skid numbers taken each time they were run at the three speeds, while Figure 14 plots the same six sites (1, 3, 6, 9, 12 and 14) against the dates at 40 miles per hour (64.4 km/hr). These figures present a general idea as to the skid resistance over the four periods of study. Figure 15 shows the average skid numbers at 30, 40 and 50 miles per hour at each site in the form of a bar-o-graph. Figure 16 shows the speed gradients plotted. They are average SN's on all sites taken on the dates shown.

Other than the face value of the numbers, it is difficult to interpret the trends of these figures. Figure 14, for instance, indicates the skid resistance rose after approximately one year of traffic (average ADT 24,000). This is explained only by the variability of skid resistance. It has long been known to those

FIGURE 13
Avg. S. N. vs. Time
For Three Speeds



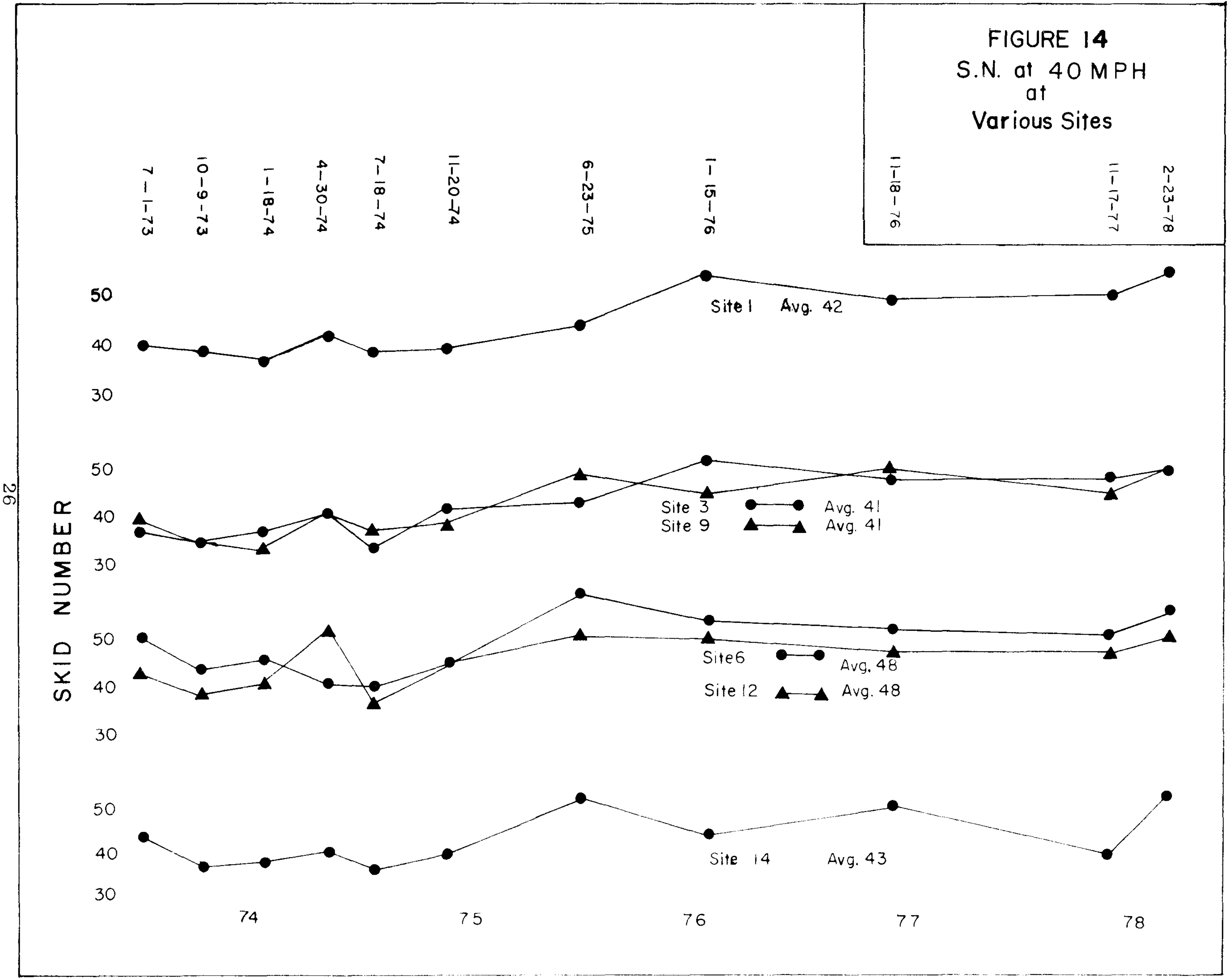


FIGURE 14
S.N. at 40 MPH
at
Various Sites

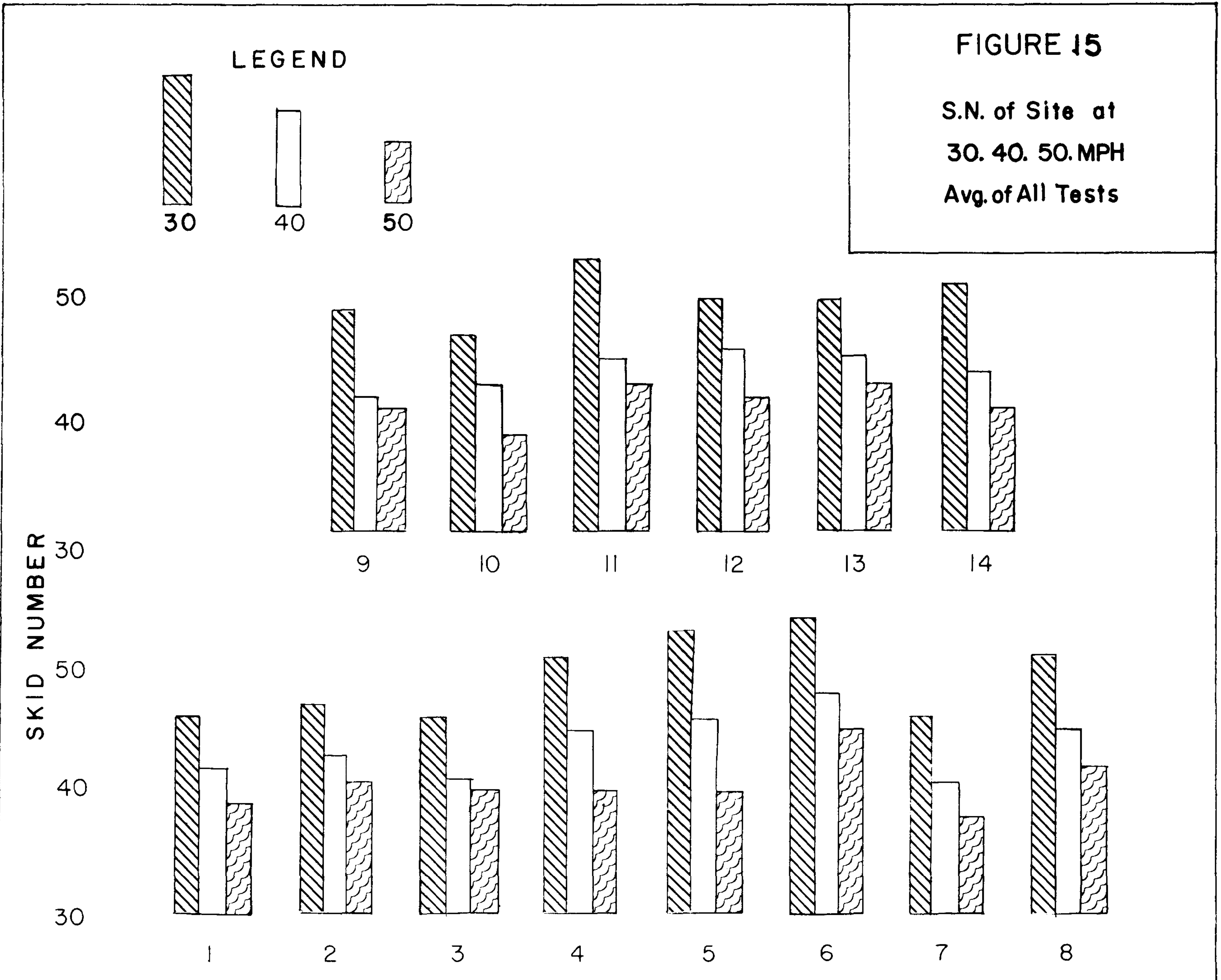


FIGURE 15

S.N. of Site at
30. 40. 50. MPH
Avg. of All Tests

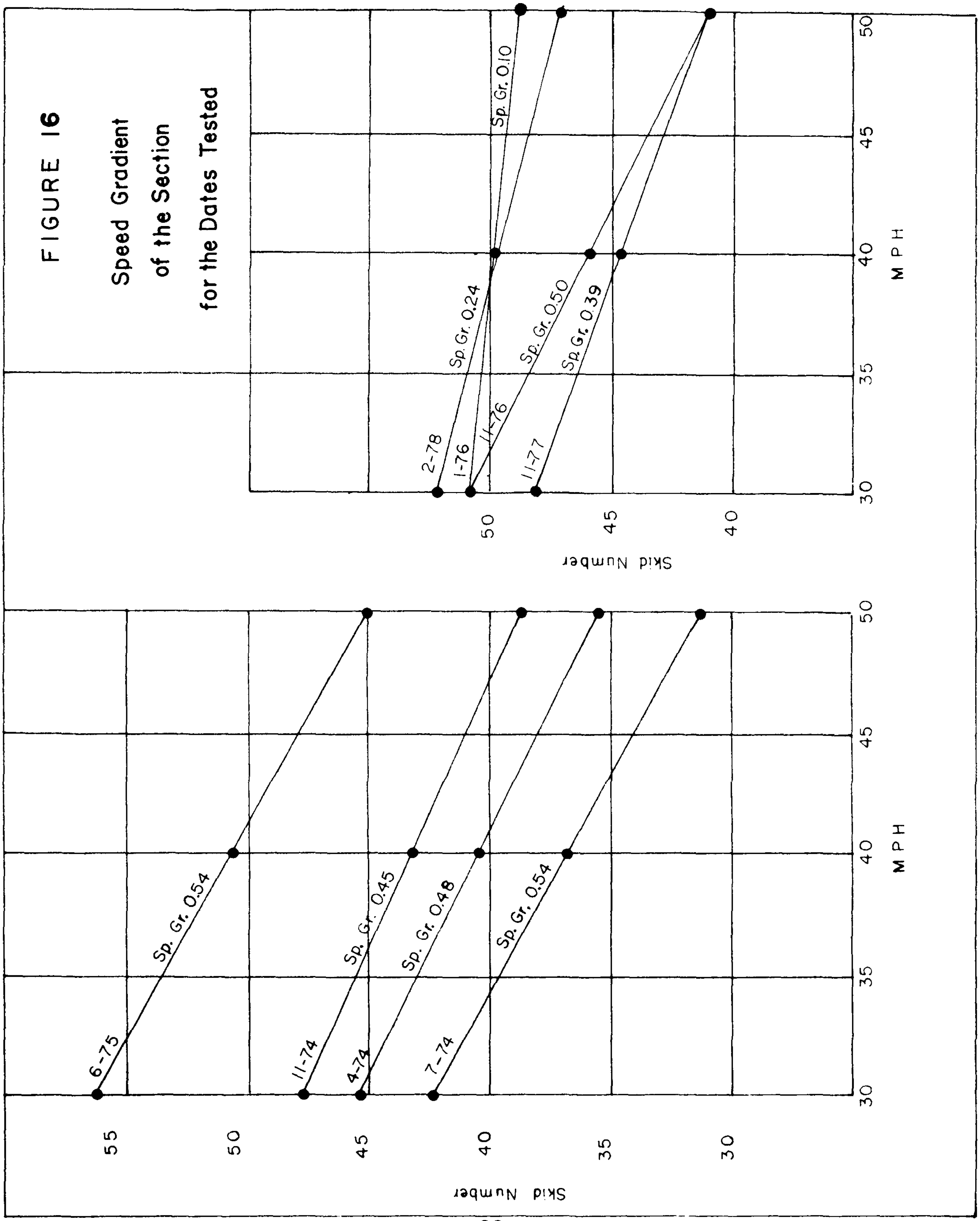


FIGURE 16
Speed Gradient
of the Section
for the Dates Tested

dealing with slippery pavements that the skid numbers are fickle, i.e., just after a trend has been established that trend blows up in his face. Even Figure 16 shows this. Speed gradients after the first year range from around 0.45 to 0.55 to anywhere from 0.10 to 0.50 thereafter.

Accident Data

There was some concern at the inception of the project whether motorcycle drivers would be disturbed by the maneuverability and/or tracking of their machines on a grooved surface. Subsequent to that concern, there was a report by G. B. Sherman et al. entitled "Effects of Pavement Grooving on Motorcycle Rideability" in which the conclusions were stated as follows:

1. In this study, the pavement grooving patterns, when evaluated with various motorcycles, did not present a hazardous riding condition. In general, the lighter machines were more sensitive to the grooving patterns; however, none had a sensitivity level sufficient to cause a control problem.
2. No individual grooving pattern was considered to be consistently superior, from a motorcycle rideability standpoint.

To point this out, there has been no increase in motorcycle accidents reported along this section of interstate since it was grooved. In the year prior to the study there were no wet weather motorcycle mishaps (one dry), and in the five years since there were no such accidents as discernable from accident reports.

Nevertheless, as a precaution, signs saying "Grooved Pavement" were placed at each entrance to warn the cyclist of any abnormal feel of "tracking" he might encounter. Another step was to have a motorcycle policeman confirm what was already known, i.e., that the pavement does not cause a significant problem. A copy of a letter to this effect is included in the appendix.

As far as larger motor vehicles go, the picture is somewhat different. There were wet weather accidents but substantially fewer on the grooved pavement than on the same pavement when it wasn't grooved. Table 1 has shown the difference between the accident rates on the section under investigation before grooving and an adjacent section of the same highway. What will be attempted in this portion of the report is to compare "after" accident rates on the grooved section to the before rates. The results are presented below.

TABLE 4

ACCIDENT RATES

		Number of Accidents			Accidents/100 MVM		
		Dry	Wet	ADT	Dry	Wet	Total
1970	1-1 to 12-31	78	32	21.7×10^3	123	50	174
1973	7-1 to 12-31	17	3	21.9×10^3	66	7	73
1974	1-1 to 12-31	39	1				
1975	1-1 to 12-31	49	7				
1976	1-1 to 12-31	65	14	32.8×10^3	85	18	102
1977	1-1 to 12-31	85	13				
1978	1-1 to 6-30	53	13				

These figures are from hand-counted accident reports and averaged ADT's over the five-year period for the study. The accident reports are hand counted so as not to include any accident that occurred on ramps or crossroads that were not grooved. The ADT's were broken up into two figures for convenience even though these figures gradually change from one to another.

Why the accident pattern jumped more than two times (both total and dry accidents) can be partially explained by the opening of I-10 southward from I-10/12 in May 1974. This would explain too the jump in ADT during the second half of the study, but the jump to four times the wet accidents during the second 2-1/2-year period (11 between 73-75 and 40 between 76-78) cannot. The wearing of the grooves is a possible partial answer.

It is difficult to ascertain why there was only one wet accident in 1974. The total inches of rainfall were less for that year, but so was 1976's rainfall as shown below.

TABLE 5

RAINFALL DATA

		Rainfall Total (Inches)	No. of Days with 0.10 or More Inches of Rain
1973	6 mos.	39.91	46
1974	12 mos.	56.97	82
1975	12 mos.	66.10	82
1976	12 mos.	51.09	73
1977	12 mos.	77.70	78
1978	6 mos.	23.94	31
	Average	63.14	78.4

(Inch = 25.4 mm)

The number of days that had 0.10 inch (2.54 mm) or more doesn't explain it either. As can be seen, 1974 was one of the two rainy years in terms of the number of days.

At any rate, the wet accident rate was reduced some 64% to 86% depending on what time of the period one wishes to examine. The grooves even produced less accidents/100 MVM than the ungrooved Mississippi River to College Drive Section.

CONCLUSIONS

The following conclusions can be drawn from this study:

1. The actual physical process of cutting grooves can be troublesome if the aggregate is hard. A micro-crystalline quartz, of which most of Louisiana's aggregate is composed, has a hardness of 7+ based on Mohs' scale of hardness. Whenever such aggregate hardness is to be encountered, the contractor should make himself aware of the fact and prepare for it.

2. The grooves have withstood the traffic reasonably well as a result of the aggregate showing signs of wear only in isolated spots along the roadway. At the sites of testing, the maximum groove wear was 0.015 inches (0.38 mm) per year in the five years of the study. Most sites, however, exhibited from 0.006 to 0.009 inches (0.15 to 0.22 mm) per year wear. Nevertheless, they are still performing even after some 50 million vehicle passes.

3. Texture depths produced little in the way of trends in spite of the "non-variability" in the testing. The fact that this section of highway had no texture to begin with, i.e., before grooving, gives rise to little wear of whatever texture there is. The degradation of the grooves evidently doesn't show up as significant to the test for texture depth. It should be pointed out that a sand patch covers only 5 or 6 grooves. The sand patch diameter did become smaller after grooving, but there it stayed.

4. The skid resistance at 40 miles per hour (64.4 km/hr) of the highway rose initially from around the 32 range up to about the 40s but fell off to the 27-38 range after the first tests, then rose again to an average of 48. Therefore, the skid numbers were improved by grooving even though it wasn't expected.

5. The accident rates were cut drastically at first, 86%, but they went up during the second half of the period of study. The rise produced a reduction in accident rates of 64%, still a substantial reduction nevertheless. Motorcycle accidents presented no problem to the study.

REFERENCES

1. Beaton, J. L., Zube, E., and Skog, J. B., "Reduction of Accidents by Pavement Grooving," Calif. Div. of Highways, HRB Special Report 101, August 1968.

2. Farnsworth, E. E., and Johnson, M. H., "Reduction of Wet Pavement Accidents on Los Angeles Metropolitan Freeways," Soc. of Automotive Engr., Two Penna. Plaza, N. Y., N. Y., Mid Year Meeting, June 1971.

3. Sherman, G. B., Skog, J. B., and Johnson, M. H., "Effect of Pavement Grooving on Motorcycle Rideability," Research Report M&R 633126-6, Calif. Div. of Highways.

4. Swertfager, W. E., "Safety Grooving in Louisiana," Highway Focus, U.S. DOT/FHWA, Vol. 8, No. 2, April 1976.

5. Walters, W. C., and Bokun, S. G., "Grooving of Concrete Pavements," La. Dept. of Highways, Research Report 70, August 1973.

APPENDIX

LOUISIANA GROOVING SPECIFICATIONS

ITEM S-1 GROOVING: The surface of the existing portland cement concrete pavement shall be grooved at the locations shown on the plans and grooving shall conform to the requirements of the plans and these specifications.

Grooved areas shall begin and end at lines normal to the pavement center lane. The grooved area of each lane shall have a minimum width of 10 feet and shall be centered within the lane width.

Grooving blades shall be 0.095 inch wide ± .003 inch and shall be spaced 3/4 inch on centers. The grooves shall be cut not less that 3/16 inch nor more than 5/16 inch deep.

The actual grooved area of any selected 2 foot by 100 foot longitudinal area of pavement specified to be grooved shall be not less than 95 percent of the selected area. Any area within the selected area not grooved shall be due only to irregularities in the pavement surface and for no other reason.

Residue from grooving operations shall not be permitted to flow across shoulders or lanes occupied by public traffic or to flow across shoulders or lanes occupied by public traffic or to flow into gutters or other drainage facilities. Solid residue resulting from grooving operations shall be removed from pavement surfaces before such residue is blown by the action of traffic or wind.

The contractor shall make every effort to insure that noise levels generated by the combined grooving operation shall not be in excess of those levels normally generated by existing truck traffic.

Pavement grooving will be measured by the square yard. The quantity of pavement grooving to be paid for will be determined by multiplying the width of the grooved area by the total horizontal length of lane grooved.

The contract price per square yard for grooving existing concrete pavement shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all work involved in grooving the existing concrete pavement, including removing residue, as shown on the plans, as specified in these special provisions, and as directed by the project engineer. Payment will be made under:

Item S-1, Grooving, per square yard.

TABLE 6

TEXTURE DEPTHS AT SITES

Site No.	7-1-73	10-9-73	1-18-74	4-30-74	7-18-74	11-20-74	6-23-75	1-15-76	11-18-76	11-17-77	2-23-78
1	.047-.037	.040-.045	.039-.038	.041-.036	.051-.047	.041-.047	.043-.047	.047-.048	--	.044-.043	.048-.038
2	.035-.036	.032-.031	.037-.036	.031-.031	.041-.050	.037-.033	.034-.035	.035-.036	--	.031-.032	.035-.030
3	.030-.030	.027-.028	.028-.027	.028-.028	.043-.040	.031-.032	.028-.029	.028-.031	--	.022-.022	.022-.022
4	.030-.031	.031-.030	.028-.030	.027-.026	.045-.044	.030-.032	.029-.032	.031-.032	--	.026-.031	.024-.031
5	.028-.031	.029-.023	.024-.028	.028-.025	.045-.025	.031-.024	.029-.022	.031-.023	--	.019-.025	.018-.025
6	.035-.035	.038-.027	.031-.038	.040-.031	.040-.055	.039-.031	.040-.031	.044-.031	--	.032-.038	.035-.040
7	.027-.027	.029-.027	.028-.031	.028-.028	.031-.035	.029-.027	.021-.026	.021-.028	--	.025-.028	.028-.026
8	.029-.023	.019-.029	.032-.023	.026-.030	.024-.034	.021-.030	.024-.030	.025-.027	--	.030-.028	.032-.032
9	.031-.034	.031-.033	.035-.031	.031-.031	.031-.037	.030-.034	.031-.032	.033-.033	--	.033-.031	.035-.033
10	.030-.026	.029-.031	.031-.029	.024-.031	.027-.031	.026-.038	.030-.034	.031-.034	--	.032-.029	.031-.028
11	.028-.028	.027-.026	.025-.027	.025-.024	.028-.027	.028-.028	.030-.028	.031-.028	--	.024-.026	.026-.024
12	.030-.031	.034-.031	.031-.032	.030-.032	.033-.032	.034-.035	.034-.037	.036-.038	--	.030-.031	.031-.031
13	.029-.028	.023-.029	.030-.024	.026-.026	.043-.044	.024-.028	.024-.026	.024-.026	--	.031-.022	.029-.022
14	.031-.029	.034-.035	.033-.037	.029-.029	.035-.035	.031-.032	.030-.033	.030-.034	--	.030-.035	.039-.036

TABLE 7

GROOVE DEPTH AT SITES

Site No.	7-73	10-73	1-74	4-74	7-74	11-74	6-75	1-76	11-77	2-78
1	0.199	0.200	0.195	0.181	0.191	0.193	0.188	0.178	0.171	0.160
2	0.125	0.114	0.099	0.111	0.117	0.109	0.092	0.113	0.059	0.071
3	0.103	0.113	0.089	0.096	0.106	0.079	0.109	0.093	0.050	0.058
4	0.137	0.128	0.119	0.104	0.125	0.107	0.109	0.113	0.093	0.083
5	0.068	0.067	0.056	0.061	0.064	0.055	0.063	0.057	0.078	0.059
6	0.118	0.091	0.099	0.117	0.110	0.104	0.122	0.090	0.054	0.051
7	0.080	0.083	0.084	0.089	0.073	0.073	0.086	0.074	0.078	0.063
8	0.085	0.068	0.064	0.055	0.059	0.050	0.063	0.051	0.050	0.052
9	0.104	0.100	0.092	0.092	0.090	0.082	0.092	0.077	0.063	0.059
10	0.085	0.109	0.090	0.083	0.101	0.090	0.091	0.083	0.081	0.058
11	0.085	0.084	0.079	0.090	0.081	0.081	0.086	0.078	0.063	0.045
12	0.132	0.129	0.119	0.125	0.126	0.128	0.125	0.125	0.104	0.109
13	0.082	0.067	0.053	0.064	0.064	0.066	0.059	0.062	0.071	0.063
14	0.098	0.138	0.135	0.145	0.150	0.129	0.133	0.126	0.104	0.104

TABLE 8

SN_{30} AT SITES

Site No.	7-1-73	10-9-73	1-18-74	4-30-74	7-18-74	11-20-74	6-23-75	1-15-76	11-18-76	11-17-77	2-23-78	Avg.
1	--	--	--	44	42	46	55	51	--	42	45	46
2				44	40	48	52	51	--	42	50	47
3				47	37	44	53	46	46	48	48	46
4				40	44	53	58	58	51	52	53	51
5				45	45	50	65	59	52	50	61	53
6				45	51	55	63	52	58	52	58	54
7				44	38	50	53	46	42	47	46	46
8				41	44	47	61	52	65	48	51	51
9				46	40	45	53	50	50	48	48	48
10				42	41	47	53	50	51	46	52	48
11				51	43	51	58	48	51	48	62	52
12				57	43	46	53	47	47	47	48	49
13				43	38	46	55	51	50	50	56	49
14				44	42	47	55	51	53	54	54	50
Average				45	42	48	56	51	51	48	52	49

TABLE 9

SN_{40} AT SITES

Site No.	7-1-73	10-9-73	1-18-74	4-30-74	7-18-74	11-20-74	6-23-75	1-15-76	11-18-76	11-17-77	2-23-78	Avg.
1	40	37	36	42	37	30	44	54	45	45	49	42
2	41	38	38	41	37	44	44	55	41	46	45	43
3	37	34	36	40	33	41	42	51	40	47	49	41
4	43	34	40	36	41	42	58	53	49	47	52	45
5	46	37	39	40	41	56	51	48	46	56	51	46
6	50	43	45	40	39	44	58	52	53	50	55	48
7	43	37	38	37	37	44	46	45	41	41	47	41
8	39	42	38	36	36	41	61	48	55	45	50	45
9	39	34	33	40	36	39	48	44	45	45	49	41
10	40	36	36	38	36	41	51	45	51	41	44	42
11	42	37	37	44	36	45	53	47	51	45	45	44
12	42	37	40	52	37	45	51	50	47	47	50	45
13	41	34	36	41	39	40	52	51	45	45	60	44
14	43	37	38	41	37	40	52	44	50	40	53	43
Average	39	37	42	41	37	43	51	49	47	46	50	44

TABLE 10

SN_{50} AT SITES

Site No.	7-1-73	10-9-73	1-18-74	4-30-74	7-18-74	11-20-74	6-23-75	1-15-76	11-18-76	11-17-77	2-23-78	Avg.
1	--	--	32	35	34	37	42	54	39	40	41	39
2	--	--	32	33	32	42	44	51	44	40	51	41
3	--	--	30	33	30	36	46	52	36	40	52	40
4	--	--	34	33	34	39	44	51	41	40	48	40
5	--	--	36	35	39	40	45	44	39	40	43	40
6	--	--	40	37	43	50	52	51	40	46	48	45
7	--	--	41	33	30	40	44	43	31	38	38	38
8	--	--	36	33	34	44	46	42	43	46	54	42
9	--	--	33	37	30	32	41	52	40	42	52	40
10	--	--	30	34	32	37	42	44	42	38	45	38
11	--	--	36	39	36	36	48	48	42	42	48	42
12	--	--	31	46	33	34	46	--	45	45	46	41
13	--	--	34	41	32	41	44	48	44	40	55	42
14	--	--	38	41	--	36	45	45	39	40	38	40
Average			34	36	31	39	45	48	40	41	47	41

CITY OF BATON ROUGE
and PARISH OF EAST BATON ROUGE
P. O. BOX 2406
Baton Rouge, Louisiana 70821

POLICE DEPARTMENT

May 15, 1973

TO: Major W. R. Ashford

FROM: Sgt. C. A. Kimberly

SUBJECT: ROAD CONDITION ON INTERSTATE

On 5-15-73, the road surface was checked on the Interstate east of College on the Honda and the Harley Motorcycle. The road surface is more than adequate for motorcycle riding. This was checked at various speeds.

This is for your information and guidance.

Respectfully,

Sgt. C. A. Kimberly
Traffic Division

CAK/dew