METHODS OF INCREASING THE HARSHNESS OF TEXTURE OF OLD CONCRETE PAVEMENTS — ACID ETCHING

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

Of the four acids tested in the laboratory, the nitric and hydrochloric types were selected for field experiments. These two acids performed about equally well, the choice as to which to use is dictated by price and availability.

In the field experiments it was found that the application of acid raised the skid resistance by 15 skid numbers, which is a significant increase; however, the increase in skid resistance is only temporary — lasting not more than six or seven months.

In cases where action must be taken immediately and equipment is not available to give a more permanent increase in skid resistance, acid etching can be used as a temporary measure. Some caution must be exercised in the use of the acids so that they are not allowed to come in contact with cars because they might mar the painted surfaces. More importantly, precautions must be taken to prevent personnel from getting the acid on their skin or from breathing its fumes. In this experiment, personnel wore rubber boots, rubber aprons, and respirators.

There was no observable damage to the environment.

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INTRODUCTION

From analyses of the results of numerous skid tests performed on portland cement concrete pavements under wet conditions, it is evident that they become slippery after vehicle passes in the range of from 20 to 25 million.[1] As used here "slippery", refers to a stopping distance number (SN)* of less than 40, the value permitted on Virginia roads.[2] The problem of slippery concrete pavement is a nationwide one as is shown by the numerous "slippery when wet" signs that abound over the nation's highways. In a 1969 survey, 40% of the states reported that slipperiness of concrete pavements was a problem.[3] A survey update in 1971 showed 24 states reporting a problem.[4]

The skid resistance of a concrete pavement is provided by the fine aggregate. When the sandpaper texture is worn away to expose the cement, the pavement becomes slippery. In former years concrete texturing in Virginia was accomplished by finishing the surface with one pass of a single-layer burlap drag. More recently, because of the detection of slippery concrete pavements, harsher textures have been built into new pavements through several different finishing methods.

The hypothesis behind the acid etching experiment reported here was that the acid would interact with the cement and remove it down to a point where the fine aggregate (sand) below the surface would be exposed.

The study was the last in a series conducted to determine methods for increasing the harshness of old concrete pavements to increase their skid resistance.

PURPOSE

The specific purpose of the experiment was to determine if acid etching could be used to effectively increase the skid resistance of old concrete pavements. Other objectives were to determine:

1. The most effective kind of acid,
2. the optimum rate of application,
3. the optimum strength of acid to be used, and
4. the optimum reaction time.

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* SN = Stopping distance number = coefficient of friction x 100

LITERATURE REVIEW AND A PRIOR EXPERIMENT WITH ACID ETCHING

Literature Review

According to a survey conducted by the writer, seven states have experimented with acid etching as a method of increasing skid resistance on concrete pavements. Five reported that acid etching was successful as a temporary solution; one reported it unsuccessful; and one did not report its results.[5] Thus the states that have used acid etching are not in complete agreement as to its effectiveness; nor are they in agreement as to the optimum strength and type of acid to be used. However, the consensus is that acid etching is a good method for temporarily deslicking concrete pavements. Immediately after application, the skid number may increase as much as 20 units; but within a period of six months, it reverts to the before-treatment level.

Prior Experiment

In 1969 the Virginia Highway and Transportation Research Council performed an experiment with acid etching in the southbound traffic lane of Interstate 95 at its junction with Route 301 in Emporia.[6] Two acids were used. One, SP-3, is a commercial product sold by the Slip-Pruf Company and advertised as a pavement deslicking material. The SP-3 was diluted hydroflouric acid. The manufacturers recommended one pint of acid mixed with nine pints of water. The other muriatic acid (Hydrochloric), is a commercial product used for cleaning bricks. Table 1 summarizes the results of that experiment.

Table 1. Skid Test Results Before and After Treatment
(40 mph predicted car values)

Type of Treatment	Ratio Water/Acid	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	4-1	45	62	47
Muriatic Acid	1-1	44	63	42
SP-3	9-1	51	56	45
Muriatic Acid	2-1	49	59	48

From Table 1 it may be seen that muriatic acid mixed in a 1:1 ratio raised the skid resistance by 19 skid numbers immediately after treatment; but six months after treatment it had returned to its original level.

PRESENT EXPERIMENT

The recent research was divided into three parts; the laboratory experiment, the small field experiment, and the major field experiment. Each of these will be discussed separately.

Laboratory Experiment

The laboratory tests were made in the summer of 1973 and involved the use of various acids at various strengths. The purpose was to determine the relative effectiveness of the acids in roughening the surfaces when applied to concrete slabs. The acids used were nitric (HNO_3), sulfuric (H_2SO_4), hydrochloric (HcL), and hydroflouric (HF). Each was applied to test concrete slabs in the laboratory at 100%, 75%, 50%, and 25% strengths. These dilutions correspond to the molarities listed in Table 2.

Table 2. Molarity of Acids at Different Dilutions

Acid Type*	Strengths			
	100%	75%	50%	25%
HNO_3	7.91	6.0	3.9	1.9
H_2SO_4	18.66	14.0	9.2	4.6
HcL	13.14	6.6	10.0	3.3

*Not Available for HF

Test slabs measuring 2' x 2' x 4" were fabricated in the laboratory from a standard concrete mix as described in Table 3. The slabs were divided into quarters

Table 3. Gradation of Coarse Aggregate in Mix Design for Concrete Slabs

Sieve Size	% Passing
3/4"	20
1/2"	37
3/8"	33
#4	10

Type A-3 mix 6 1/4 bags/ cubic yard.

and 25%, 50%, and 75% solutions of acid were applied to separate quarters, with one quarter being used as a control.

The surface temperature of all of the test slabs was 100°F. The reaction times were noted by the effervescent from the surface of the concrete. After the elapsed times shown in Table 4 no further reaction could be detected although a high degree of acidity was still shown by the acid indicators. It is believed that the residue from the early reaction prohibited further reaction.

The slabs were thoroughly washed and the skid resistance of the control and test sections were measured with a British portable tester. Table 5 gives these results obtained from the British portable tester and predicted stopping distance numbers from a conversion chart.

Table 4. Reaction Time for Different Strength Acids

Acid Type	Strength, %	Reaction Time (min.)	pH When Reaction Complete
HNO_3	100	6	—
	75	5	1
	50	6	2
	25	3	2
H_2SO_4	100	10	—
	75	17	2
	50	11	2
	25	8	2
HcL	100	4	—
	75	7	1
	50	6	2
	25	8	2
HF	100	—	—
	75	8	1
	50	8	2
	25	6	2

Table 5. Skid Resistance of Concrete Slabs Treated with Acids at Different Strengths

Acid	Strength	BPN*	PSDN**	Strength	BPN	PSDN	Strength	BPN	PSDN	Control BPN	Control PSDN
HNO_3	75%	83.8	78	50%	86.5	82	25%	93.5	90	51.5	45
H_2SO_4		83	78		88.5	86		89	86	73	69
HcL		85.5	81		91	86		87.7	83	74.5	71
HF		82.4	77		79	75		82.5	78	61	56

* British Portable Tester Number
** Predicted Stopping Distance Number

A separate test slab was used to compare the results of the full strength with the Hydroflouric type being omitted because of its poor showing in the previous tests. Table 6 shows these results.

Table 6. Skid Resistance of Slabs Treated with Acids at 100% Strength

Acid	BPN*	PSDN**	Control BPN	Control PSDN
HNO_3	85	81	68	64
H_2SO_4	80.8	76	68	64
HcL	77.6	73	68	64

* British Portable Tester Number
** Predicted Stopping Distance Number

Figure 1 is a graphical representation of the four acids, their strengths, and the skid resistance in both predicted car numbers and British portable tester numbers.

As the graph indicates, a 25% strength is as good as or better than 50% for all acids. To verify this result, one-half of a slab was treated with a 25% hydrochloric acid and the other half with a 50% hydrochloric acid. For each half, the application rate was 100 ml/ft^2. After treatment the BPN for the 50% section was 81.6 and that for the 25% section was 90.5.

It was observed throughout the experiment that the BPN's tended to be low just after the acid application, but within an hour or two showed a sharp increase.

Since the laboratory experiment was performed on slabs of new concrete, it was decided to perform a small field experiment on an old, well traveled concrete pavement.

First Experiment on Route 58

The site selected for the field experiment was Route 58 in Greensville County, a two-lane jointed concrete pavement built in 1952. The site was directly in front of the old Area Headquarters at milepost 0.40. Figure 2 shows the layout of the test squares, which measured 2' x 2'.

At plots 1 and 4 nitric acid was applied at the rate of 100 ml/ft^2 at 25% strength, and at plots 2 and 3 the same application was made using hydrochloric acid. The areas were washed and the skid resistance was checked with the British portable tester. The test plots were then subjected to a second application at the same rates and strengths and allowed to react for six minutes. They were then washed again with water and the skid resistance was checked. The increase in skid numbers ranged from a high of 20 to a low of 1. Figure 3 gives the results of these experiments.

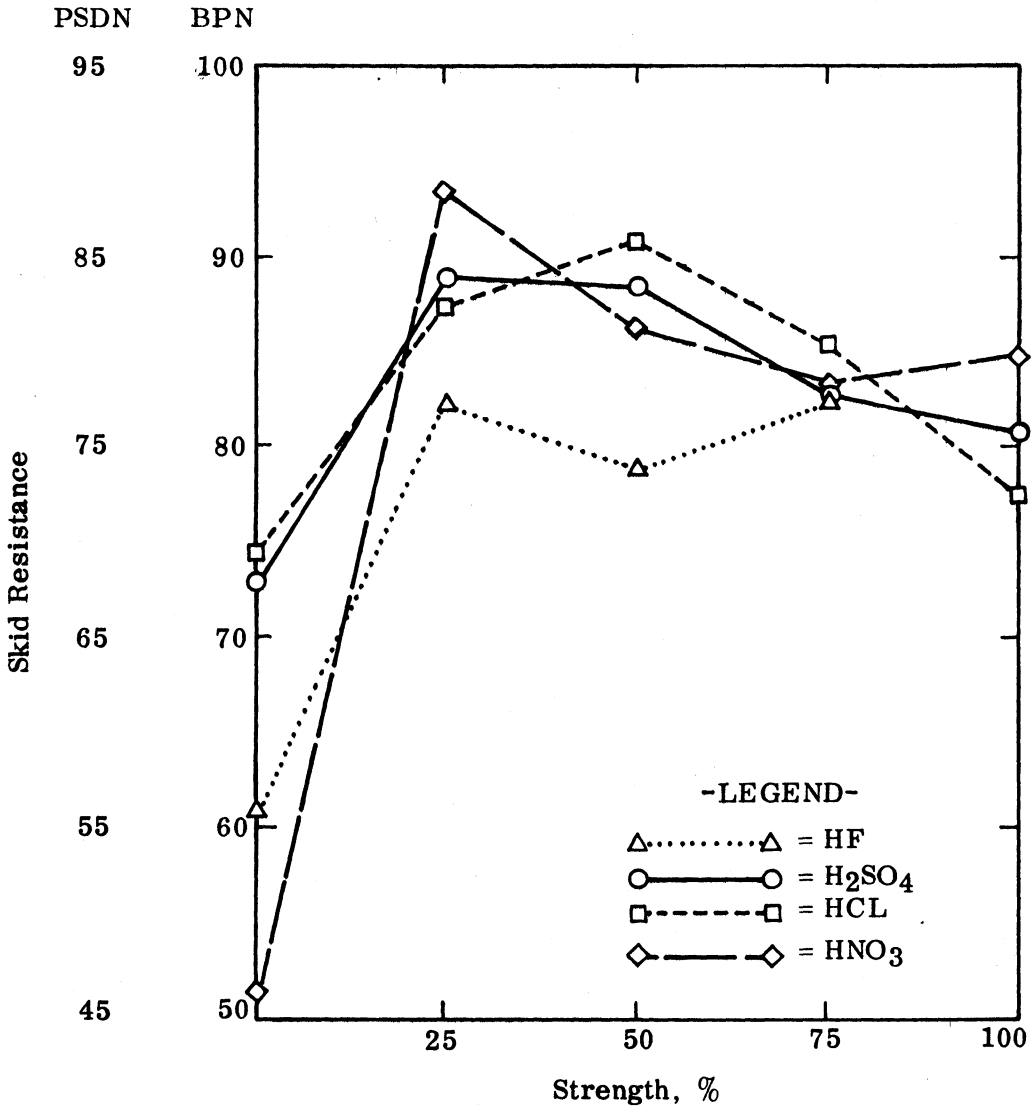

Figure 1. Results of laboratory tests.

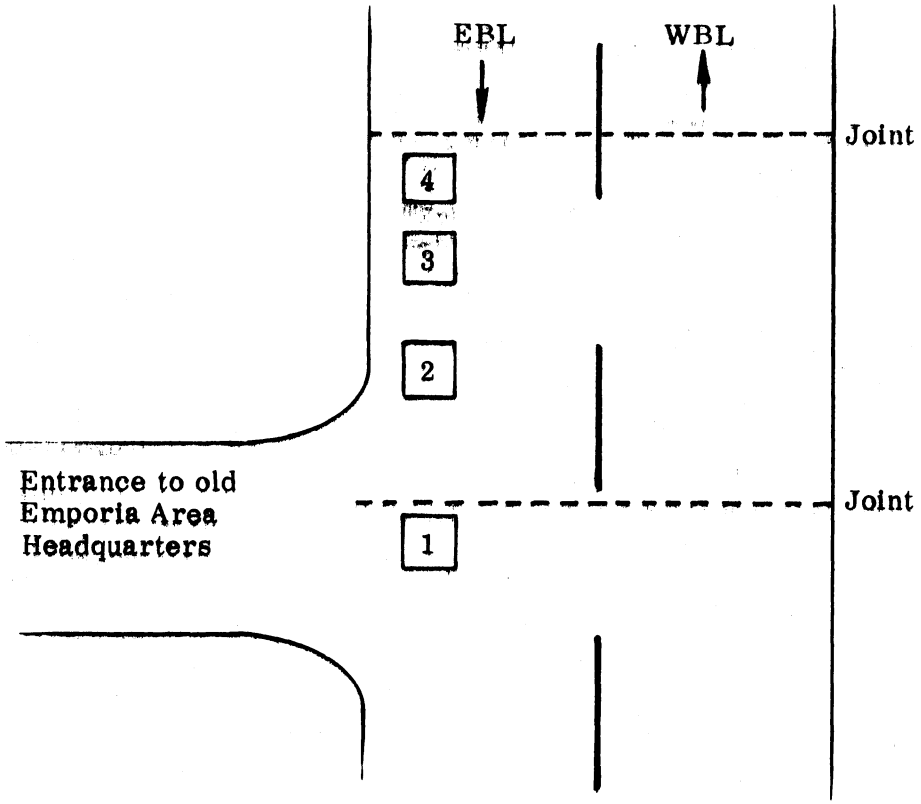

Figure 2. Acid test plots on Rt. 58, Greensville County.

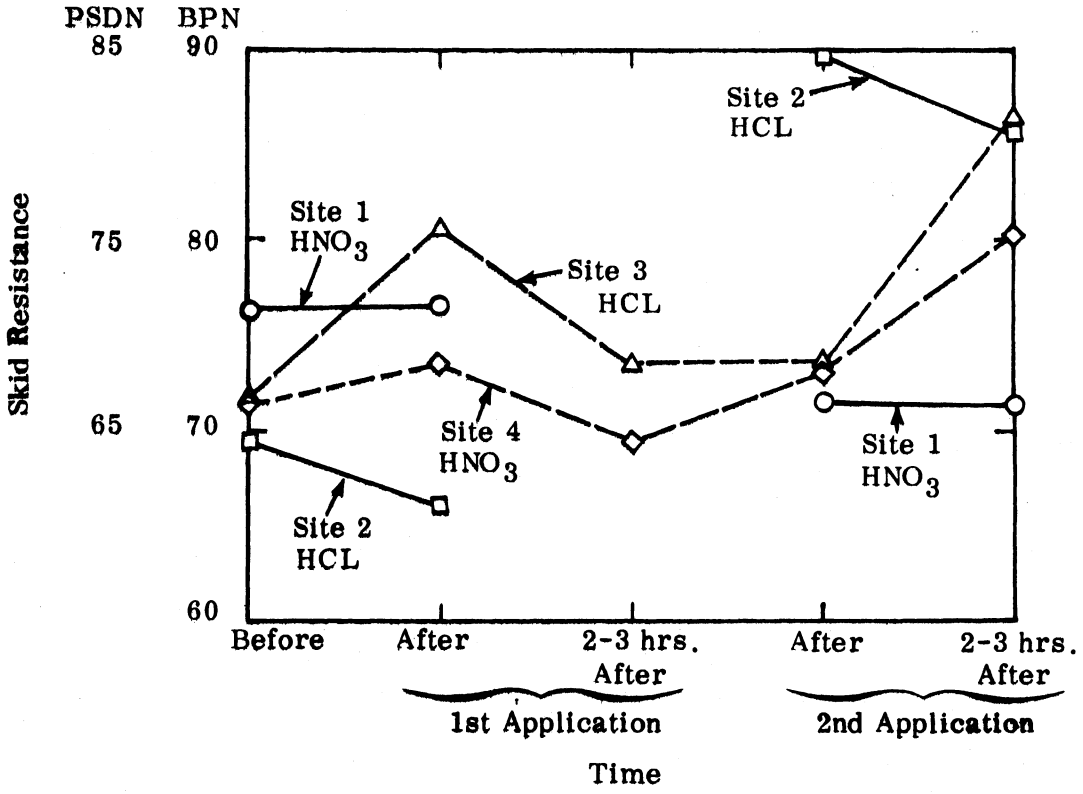

Figure 3. Results of acid tests on 2' x 2' squares on Route 58.

It may be noted that apparently unusual things may occur with the application of acid. For example, with one application of hydrochloric acid at plot 2 the skid resistance actually decreased. The author believes that this is one of the cases in which the skid resistance decreased immediately after the application and not enough time was allowed for the skid resistance to go back up. At the second application on the same plot the skid resistance increased by twenty numbers. The decision was made to conduct a full-scale experiment large enough to test with the skid test trailer and the skid test car.

Full-Scale Experiment on Route 58, Greensville County

Location

The site selected for the full-scale experiment was in the eastbound lane of Route 58 in Southampton County, 0.6 mile east of the Greensville County line. Five test sections, each 150 feet in length and 12 feet wide, were established. Site 1 served as a control site; site 2 had one application of 25% hydrochloric acid; site 3 had two applications of 25% hydrochloric acid; site 4 had one application of 25% nitric acid; and site 5 had two applications of 25% nitric acid.

Equipment

The equipment used to apply the acid to the road consisted of a spray bar assembly, a supply tank, and an apparatus to suspend the spray bar. The vehicle used was a pickup truck.

The spray bar was assembled from chlorinated polyvinal chloride (CPVC), which is a hot and cold water plastic pipe. To test the pipe before usage, a section was placed in full strength solutions of hydrochloric acid and nitric acid for 30 minutes each. The pipe was cut and assembled so that it fit the tailgate of a pickup truck and covered the full width of the roadway. A section of pipe was used to connect the spray bar to the supply tank. The supply tank was a 55 gallon linear polyethylene drum with a spigot and lid. The apparatus used to suspend the spray bar above the tailgate was constructed from 2" x 4" and 1" x 2" lumber. The spray bar was suspended so as to allow for a lateral swinging motion to spread the acid completely. Nylon lines were used to support the spray bar. Figure 4 is a diagram of the equipment and Figure 5 shows it in place in the truck.

Application of Acids

The acids were applied evenly over the test areas as described previously, 36 gallons on sites 2 and 4, and double applications on sites 3 and 5. The acid was applied to a dry surface and allowed to react for 10 minutes. Figure 6 shows the acid being applied. Note the even coverage obtained by hand swinging the spreading bar from side to side. Traffic was maintained in the adjacent lane during the operation.

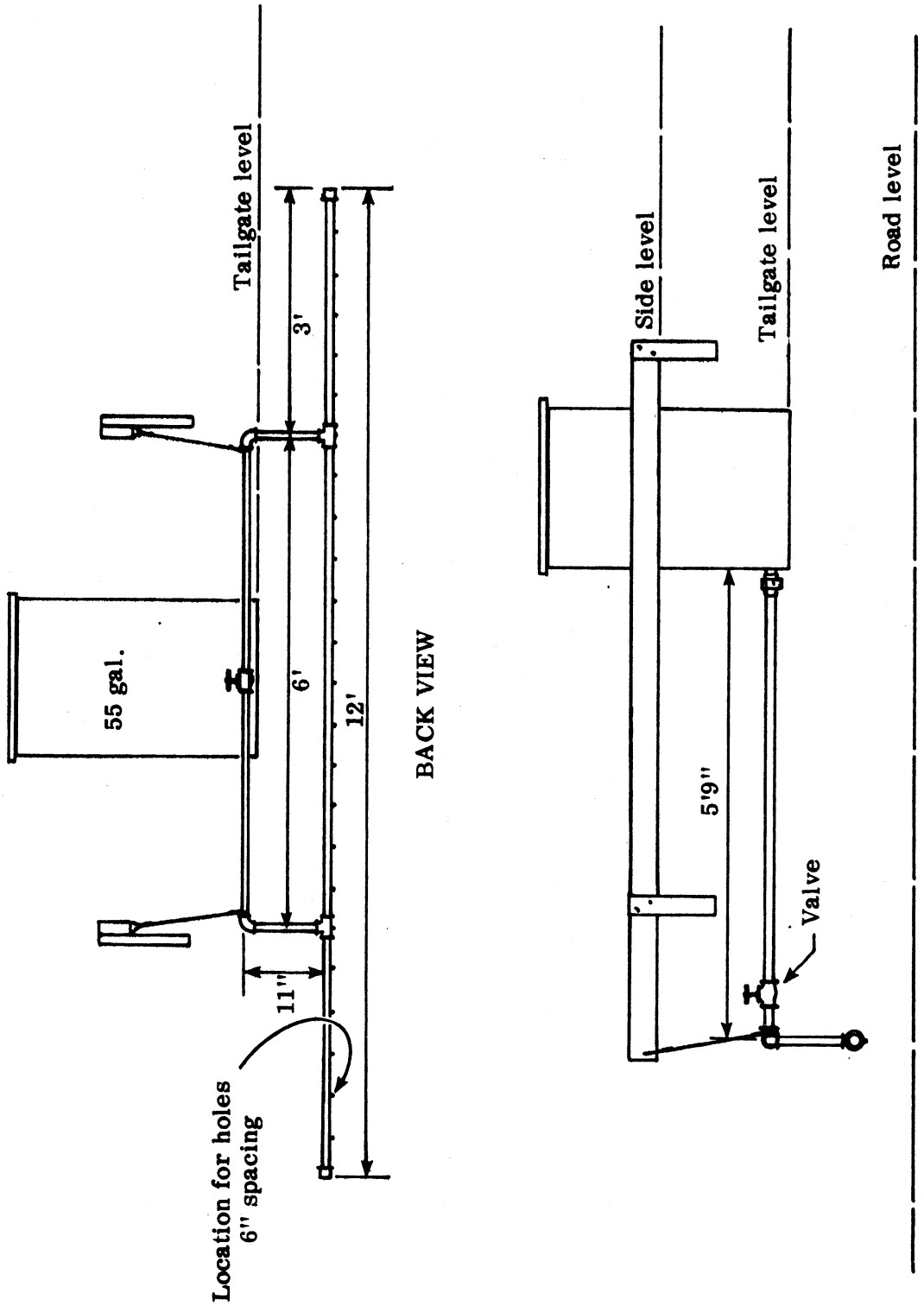

Figure 4. Diagram of apparatus for spreading acid.

Figure 5. Apparatus for spreading acid.

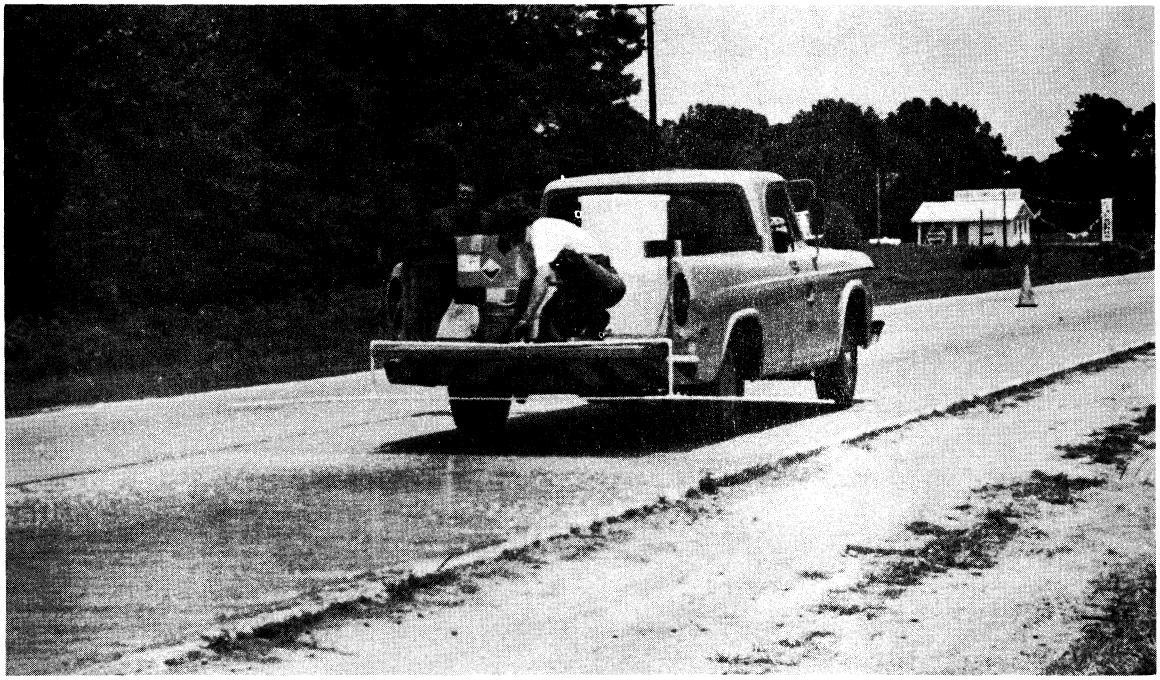

Figure 6. Acid being applied to roadway.

The acid completely cleaned the surface and left it lunar white in color after drying. The sandpaper texture was improved. Table 7 lists the results of skid data tests made with the Research Council's trailer immediately after the acid application.

Table 7. Skid Data for Route 58, Southampton County

Condition	Sites				
	1 (Control)	2	3	4	5
Before	53	51	53	49	53
1st Application	52	61	63	63	63
2nd Application	53	—	64	—	65
One Day After	54	61	67	64	68

On site 2, where one application of hydrochloric acid was applied, the skid resistance was raised 10 skid numbers as measured on the day of application and the day after. On site 3, where two applications of hydrochloric acid were made, the skid resistance was raised 11 skid numbers on the day of application and 14 skid numbers on the following day. On site 4, where one application of nitric acid was applied, the increase in skid resistance was 14 skid numbers on the day of application and 15 the day after. On site 5, where two applications of nitric acid were made, the increase was 12 skid numbers on the day of application and 15 the following day. As may be seen, the skid resistance was raised significantly on these sections. From the test, however, it does not seem justified to use two applications of acid as the skid resistance was raised only three numbers by the second application.

Skid tests were performed after seven months had elapsed and Table 8 shows these results.

Table 8. Skid Test Results — Day After Application and Seven Months Later

Condition	Sites				
	1 (Control)	2	3	4	5
Before Treatment	53	51	53	49	53
One Day After	54	61	67	64	68
Seven Months After	52	56	56	56	57

It may be noted from the table that the skid resistance of the pavement decreased considerably in seven months and was only slightly higher than before the treatment.

CONCLUSIONS

1. Acid etching can be used successfully as a temporary measure for increasing the skid resistance of concrete pavements.

2. A 25% solution at 100 milliliters per square foot appears to be the optimum application.

3. After a 6-10 minute reaction between the acid and concrete a residue is formed, probably a calcium salt, that greatly retards further reaction.

4. A second application of acid does not seem justified by the increase in skid numbers it provides.

5. The two acids selected for the final tests, nitric and hydrochloric, are about equal in their effectiveness in increasing skid resistance.

RECOMMENDATION

It is recommended that hydrochloric or nitric acid at 25% strength and a rate of 100 ml/ft^2 be applied to concrete pavements as an emergency or temporary solution to increase the skid resistance of slick pavements, with due observance of the necessary precautions.

ACKNOWLEDGEMENT

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