Technical Report Documentation Page

1. REPORT No.
CA-DOT-TL-3146-1-75-17

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Skid Testing Proposed "Standard" Pavement Surfaces

5. REPORT DATE
May 1975

6. PERFORMING ORGANIZATION
19304-762504-643146

7. AUTHOR(S)
Apostolos, John A.

8. PERFORMING ORGANIZATION REPORT No.
CA-DOT-TL-3146-1-75-17

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Transportation Laboratory
5900 Folsom Boulevard
Sacramento, California 95819

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS
California Department of Transportation
Division of Construction and Research
Sacramento. California 95807

13. TYPE OF REPORT & PERIOD COVERED
Final- December 1974 to May 1975

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT
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17. KEYWORDS
Skid resistance testing, standards, surface properties, metals

18. No. OF PAGES:
47

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1974-1975/75-17.pdf

20. FILE NAME
75-17.pdf

DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY
RESEARCH REPORT

SKID TESTING PROPOSED "STANDARD" PAVEMENT SURFACES

FINAL REPORT
CA - DOT - TL - 3146 - 1 - 75 - 17
MAY 1975

75-17

Caltrans
CALIFORNIA DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.

4. TITLE AND SUBTITLE	5. REPORT DATE
SKID TESTING PROPOSED "STANDARD" PAVEMENT SURFACES	May 1975
	6. PERFORMING ORGANIZATION CODE 19304-762504-643146
7. AUTHOR(S) Apostolos, John A.	8. PERFORMING ORGANIZATION REPORT NO. CA-DOT-TL-3146-1-75-17
9. PERFORMING ORGANIZATION NAME AND ADDRESS Transportation Laboratory 5900 Folsom Boulevard Sacramento, California 95819	10. WORK UNIT NO. 11. CONTRACT OR GRANT NO.
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17. KEY WORDS	18. DISTRIBUTION STATEMENT
Skid resistance testing, standards, surface properties, metals.	Unlimited

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	47	

HMRT 1242 (ORIG. 9/72)

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY

May 1975

TL No. 643146

Mr. R. J. Datel
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

SKID TESTING PROPOSED
"STANDARD" PAVEMENT SURFACES

Study made by . . . . Pavement Branch

Under the Supervision of . . . . John Skog

Principal Investigator . . . . John A. Apostolos

Report Prepared by . . . . John A. Apostolos

Very truly yours,

George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

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ACKNOWLEDGEMENTS

The author wishes to thank the following personnel of the Transportation Laboratory, whose combined expertise, constructive suggestions, and plain hard work made this project possible: Lloyd A. Batham III, Martin Bianco, Frank G. Boeger, Earl A. Boerger, Sylvester A. Dalske, Wesley N. Dwyer, Wesley E. Faist, Marion Ivester, Lawrence Lowe, Leonard Nordmann, Bobby G. Page, Kent S. Scovel, Harvey D. Sterner, and Gene S. Stucky.

INTRODUCTION

A currently widespread method of measuring the skid resistance of highway pavements is the towed trailer method (ASTM E274-70). Machines meeting these ASTM specifications are manufactured by several suppliers, and the need exists to correlate the values obtained with each machine to the values obtained by others. Also, due to the substantial volume of testing performed by these machines, it is necessary that they be frequently recalibrated, or "tuned." Such "tuning" is usually performed under static conditions.

The advantage of calibrating each machine and correlating several machines under dynamic conditions is generally appreciated by the agencies involved in skid testing. Thus, the need exists for "standard" pavement surfaces for dynamic calibration. Various conventional surfaces using several aggregate types and finishes have been studied*, and most exhibited an expected tendency to wear and roughen or polish, or, generally stated, to change their coefficient of friction (skid number) with wear and weathering. Another disadvantage of such conventional pavement surfaces is the practical impossibility of reconstructing identical surfaces, i.e., surfaces having the same frictional characteristics, at other sites. Thus, it becomes necessary that skid test vehicles must periodically travel to regional test centers, in order to correlate with other machines of the same type on the same surfaces. Such travelling can be quite time-consuming and expensive, since round trips to regional centers would be often in excess of 2000 miles in length. The cost of such operations tends to limit the frequency of such correlation "meets," with a resulting reduction in the confidence of data during the ensuing long intervals.

*Don L. Ivey, et. al., "Pilot Field Test and Evaluation Center," Report No. FHWA-RD-72-71, Texas Transportation Institute, April 1972.

In order to overcome the present limitations of conventional "standard" surfaces, it was proposed to study the possibility of using expanded metal mesh of various configurations to provide a range in coefficient of friction values. The proposed advantages of this system are as follows:

1. Easily reproducible texture and frictional characteristics, either by selection from conventional manufactured stock or by special order.

2. Expected to be more resistant to wear and weathering, especially with the use of stainless steel sheets, and possible environmental protection by the use of some form of covering.

3. Being lightweight and flexible, such surfaces can be skid-tested, and then shipped from regional centers to the home bases of skid test vehicles for local testing. That is, the "pavement surface" would be transported to the testers, instead of the opposite, and at a considerable cost savings.

To test this new approach, a preliminary study has been performed on the skid resistance characteristics of various metal surfaces. To avoid unnecessary cost and delays, ordinary steel was used instead of stainless steel, for this preliminary study.

CONCLUSIONS

Based on this preliminary study, the following tentative conclusions can be drawn:

1. Smooth and expanded metal sheets appear to have excellent potential as "standard" surfaces for dynamic calibration of skid test vehicles.

2. Coefficient of friction values from the expanded metal surfaces were as repeatable and consistent as the values from the control dense-graded asphalt concrete (AC) surface.

3. Skid number vs. speed gradients from the standard expanded metal appear to be similar to the gradients from the control surface.

In addition, the following observations are offered:

1. A 16 to 20 foot long section appears adequate for obtaining confident repeatable skid test values at 40 mph.

2. Sandblasting expanded metal surfaces prior to use is necessary to prevent unusual tire damage due to sharp edges.

3. Shipment of expanded metal would be easy and economical (a 4' x 40' section would weigh approximately 135 lbs.).

4. Welding several sheets together to create a continuous long section (as in this study) is not recommended due to potential warpage. A 3" to 4" free overlap of sheets, with some bevelling to reduce the resulting "bump" would be preferable.

5. Accumulation of test water on the surfaces under continuous testing is inevitable. A cross-slope of 2% allowed the accumulation (and thus the coefficient of friction) to reach steady-state conditions after 3 to 5 runs.

6. Measurable variation in frictional values exists in expanded metal sheets meeting identical specifications. This is due to the latitude in the tolerances of sheet thickness, and in the "cut-and-pull" method of manufacture. Special order must be

used to obtain matching sheets from the same run and by the same manufacturer. Alternatively, punch dies may be designed for use with sheet stainless steel rolls.

IMPLEMENTATION

It is recommended that smooth sheet steel and expanded metal (stainless steel) surfaces be used as a portion of the "standard" pavement surfaces proposed for the dynamic calibration facility currently under construction at the California Highway Patrol Academy in Bryte, California.

Appendix A contains the proposed set of plans for the construction details of the actual skid test area. These plans reflect considerations for both conventional and unconventional (metal) surfaces; necessary cross-slope for drainage; anchorage of metal surfaces and allowance for future modifications of anchorage; wheel spacing of test vehicles to avoid possible damage to tires or 5th wheels by the anchor devices; structural requirements for the support slab; and provisions for tarpaulin cover of the metal surfaces.

In addition, the need exists for a water main, and 110V AC electricity in the immediate vicinity of the skid test area.

Assuming that further testing confirms the findings of this study regarding use of lightweight metal surfaces for skid test calibration, the following procedure is suggested for region-wide correlation:

1. Regional Center tests sheets and assigns SN values to each sheet. (These values may not be identical, even on the same type sheet.)

2. Regional Center ships a portion of the tested sheets to each local agency (along with the data).

3. Each local agency skid tests its group of sheets with their skid test vehicles, and correlates its vehicles with the Regional Center's.

4. Local agencies then exchange groups of sheets or return sheets to Regional Center for retesting. Regional Center then re-ships sheets to another local agency.

Additional research is recommended to evaluate other unconventional portable surfaces for suitability as "standards." The great variety of such surfaces should provide researchers with a wide range of coefficient of friction values. Perforated metal and light duty chain link conveyor belt material are suggested as possibilities.

DISCUSSION

1. Facilities and Test Equipment

The facilities of the California Highway Patrol Academy currently under construction at Bryte, California, include a dynamic test area. This area was designed for use by the California Department of Transportation, Transportation Laboratory for the purpose of conducting barrier crash test experiments and for dynamic calibration and other research connected with skid test vehicles. The skid test facility consists of a strip of dense-graded asphalt concrete (AC) pavement 24 feet wide and approximately 2400 feet in length. This length provides for the needed acceleration and deceleration of the 2 test vehicles currently owned by California Department of Transportation. The actual skid test area is near the center of the 2400 foot strip. Maximum test speed that can be achieved on this track is 50 mph.

Both skid test trailer vehicles used in this study conformed to ASTM E274-70 but were constructed by different manufacturers, K. J. Law Engineers, Inc. and Soiltest Inc. (For the purpose of this report, these two vehicles will be hereafter referred to as the "Law" and "Soiltest" machines.)

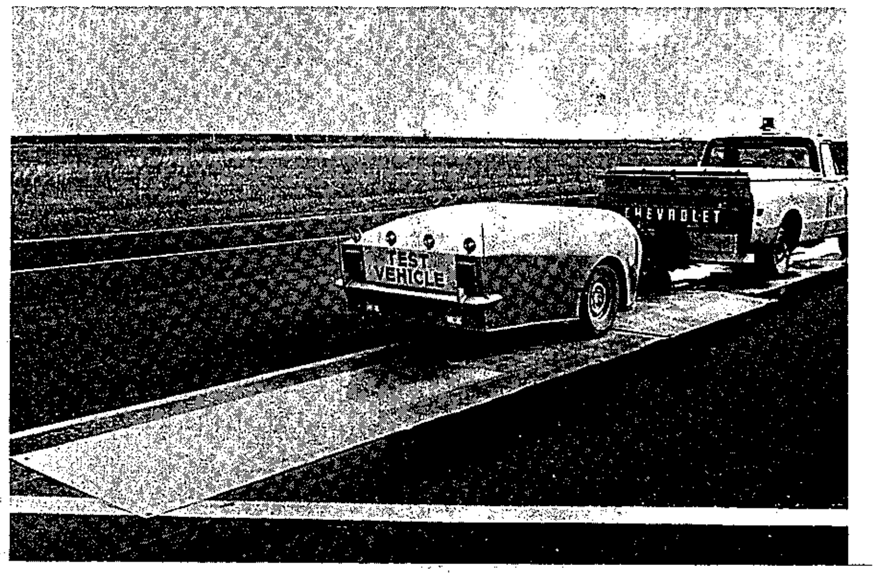


Fig. 1 The "Law" Skid Test Vehicle

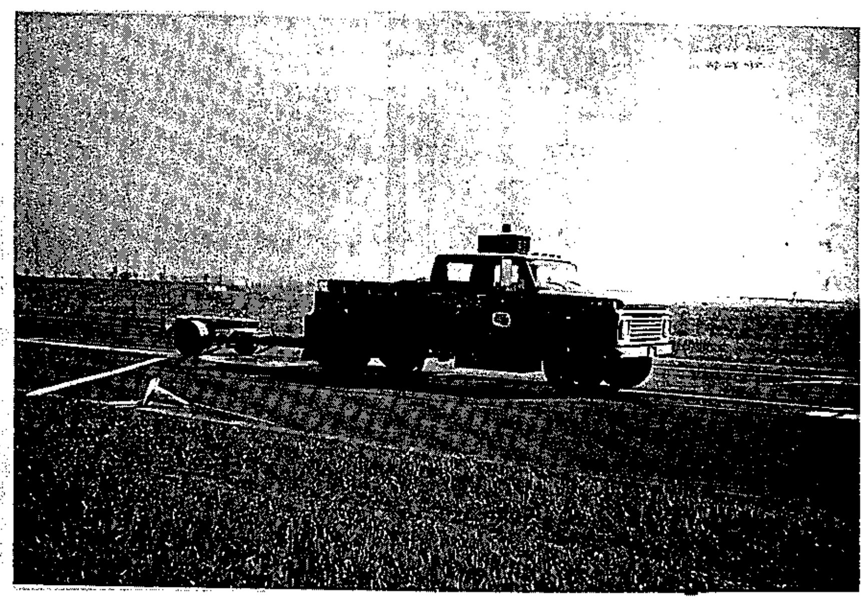
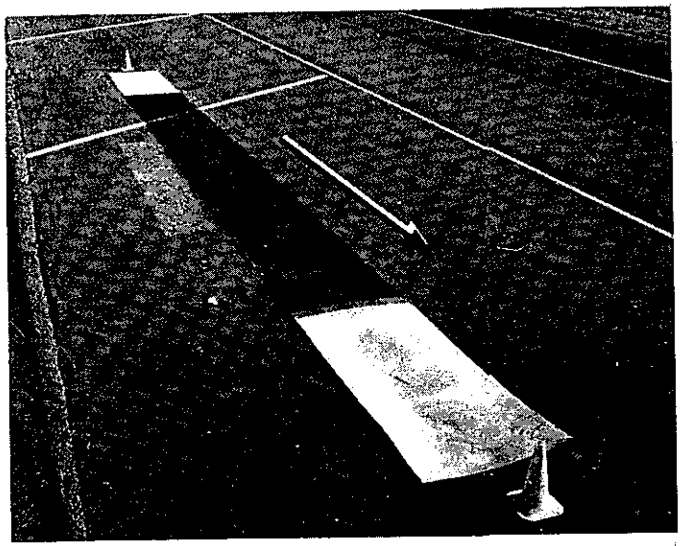


Fig. 2 The "Soiltest" Skid Test Vehicle

2. Test Sections

Two test sections were placed on the asphalt concrete test strip. Figures 3 and 4 describe these test sections "ALPHA" and "BETA", respectively, and include a typical horizontal friction force trace as recorded with the "Soiltest" machine at 40 mph. The leading galvanized sheets overlapped the first expanded metal sections by 6" to provide a "ramp" for the skidding tire. The trailing galvanized sheets were overlapped by the last expanded metal section. The expanded sheets were butt-welded together to form a continuous section.

FIGURE 3.- - TEST SECTION ALPHA

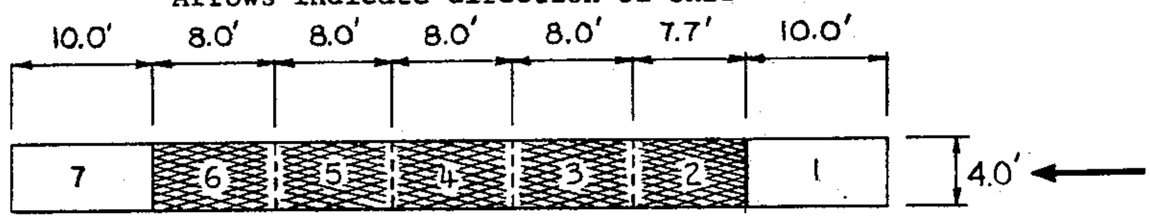


SURFACE TYPES:

1. Galvanized Steel Sheet, 20 ga.
2. Standard Expanded Metal, 1/2"-#16 ga.
3. " " " "
4. " " " "
5. " " " "
6. " " " "
7. Galvanized Steel Sheet, 20 ga.

Dotted lines indicate butt-welds.

Arrows indicate direction of skid



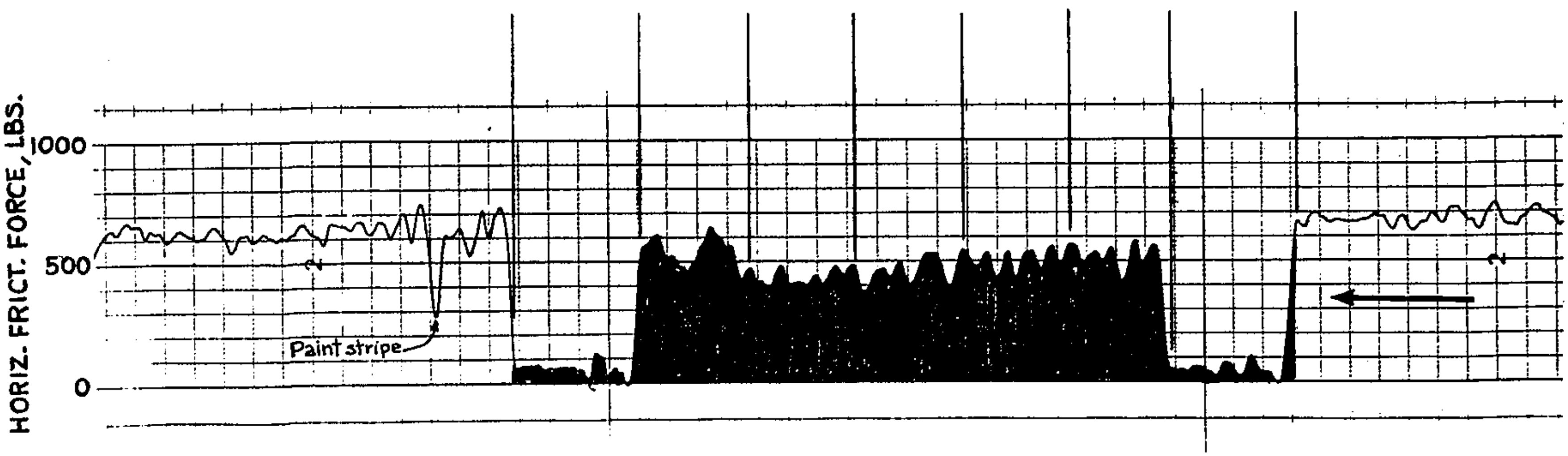
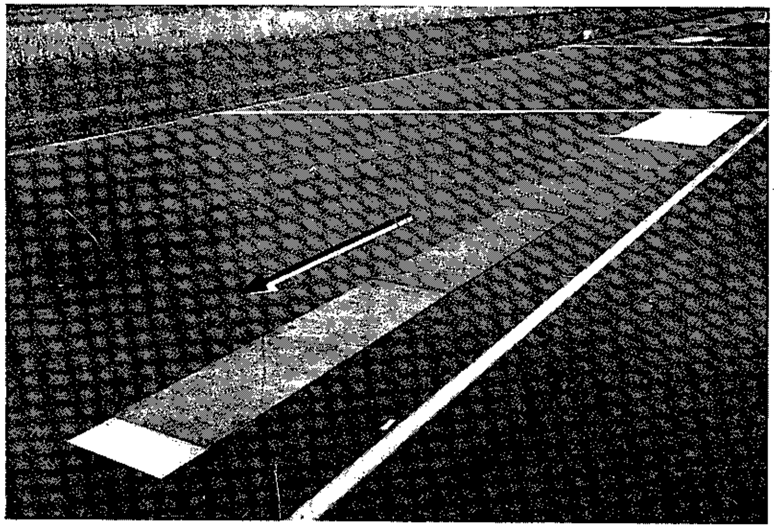


FIGURE 4.- - TEST SECTION BETA

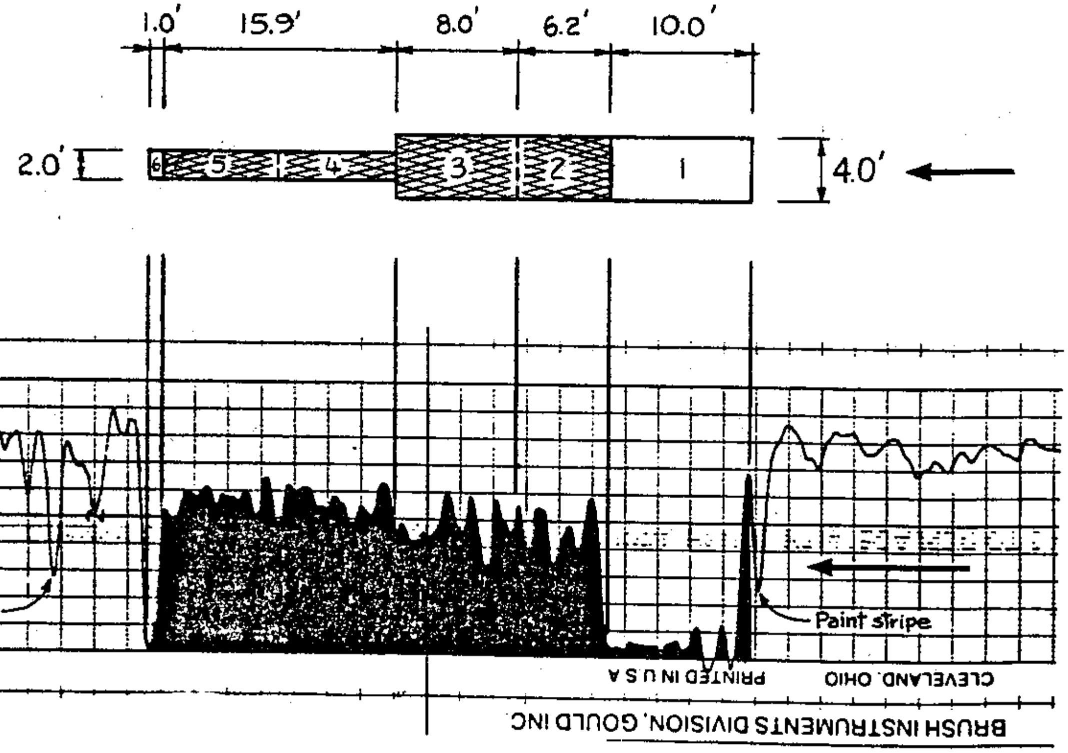


SURFACE TYPES:

1. Galvanized Steel Sheet, 20 ga.
2. Expanded Metal Flattened, 1/2"-#13 ga.
3. " " " "
4. Exp. Metal Flatt., 1/2"-16 ga. over steel sheet, 12 ga.
5. " " " " " " " "
6. Galvanized Steel Sheet, 20 ga.

Dotted lines indicate butt-welds.

Arrows indicate direction of skid.



Facilities for securing the metal sheets to the pavement were not available at the site. Successful anchorage was achieved by drilling a series of 1" diameter holes through the .15' - .24' thick AC, hollowing-out the aggregate base material, and securing the sheets by 1/4" toggle bolts and washers along each side at 4 foot intervals. This method was successful in fully securing all surfaces and restraining them from both vertical and horizontal displacement throughout the test series. One disadvantage of this extemporaneous anchorage system was that it did not include tensioning of the sheets flat against the AC pavement.

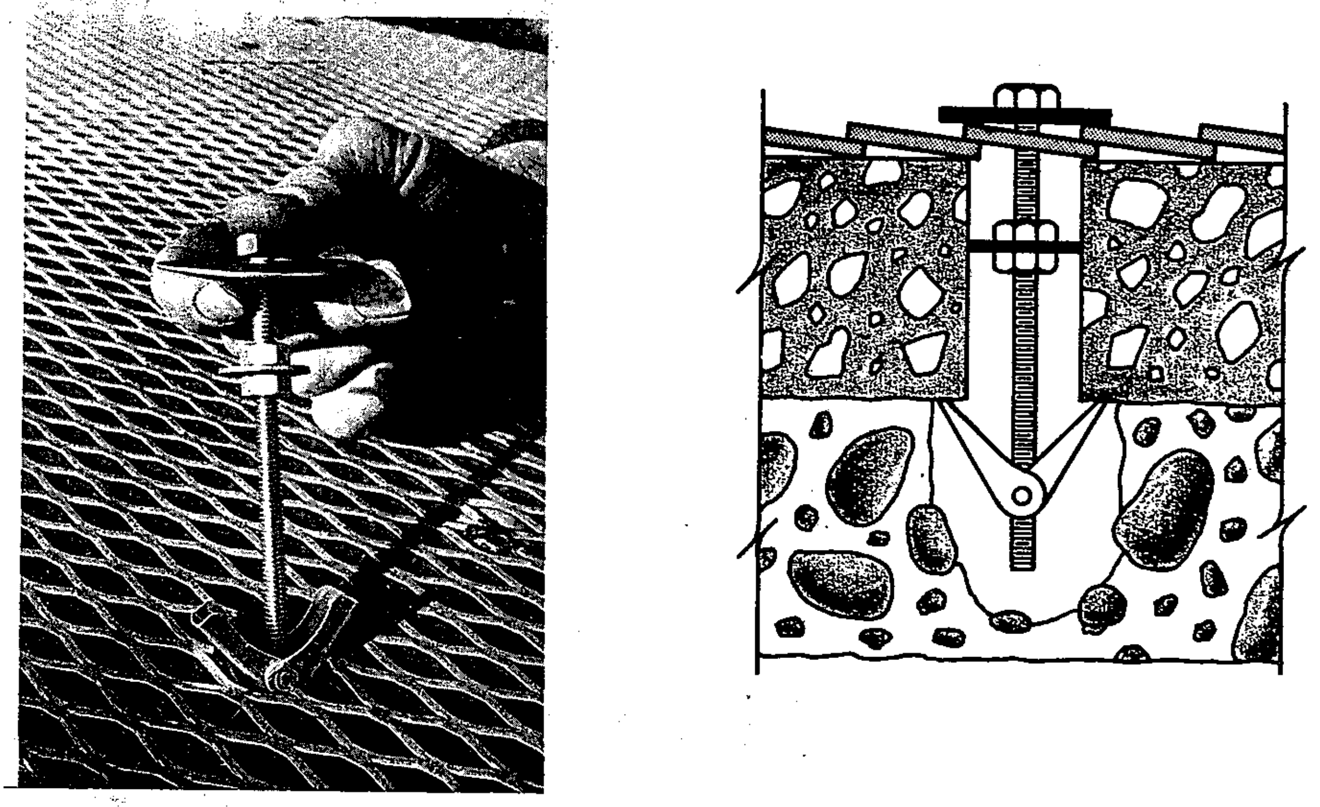


Fig. 5 Details of Anchoring Device

Due to locked-in stresses created by welding, some sheets tended to "bow up" between the anchors. The last sheet on test section ALPHA (#6 on Fig. 3) had a particularly pronounced double "bow" which was reflected in a distinctive but unusual force trace when tested. (Results from this sheet are omitted in this report.) Tensioning would help minimize such "bowing" and hold sheets flatter against the AC surface.

Test section BETA included a test surface in which bowing characteristics were eliminated by tack welding expanded metal flattened sheets to a 12 gauge steel sheet. This unit was then anchored to the AC pavement.

3. Test Method

Test times and equipment had to be coordinated with the availability of test vehicles and operators, and with the vagaries of unseasonably-wet weather. When the opportunity to use both machines simultaneously presented itself on January 27, 1975, test runs were alternated between the Law and Soiltest machines, in order to minimize effects of water buildup, wear, etc., between the two. Table 1 summarizes the total test runs performed on this project.

Table 1. Summary of Skid Test Runs

Date	Skid Test Machine	Test Section	Nominal Speed	No. of Runs	Test Tire
1-20-75	Law	ALPHA	40 mph	45	Rib
1-27-75	"	"	40	29	"
"	"	"	30	1	"
"	Soiltest	"	40	28	"
"	"	"	30	1	"
1-30-75	"	"	40	25	"
"	"	"	40	10	Smooth
"	"	"	30	10	Rib
"	"	"	50	1	Smooth
2-10-75	Law	"	40	25	Rib
"	"	"	30	5	"
"	"	"	50	5	"
"	"	"	40 (no water)	2	"
January 1975	Additional runs not recorded.			6	"
1-24-75	Law	BETA	40	35	"
"	"	"	30	5	"
"	"	"	50	5	"
1-25-75	Soiltest	"	40	18	"

Total runs on Test Section ALPHA 193

Total runs on Test Section BETA 63

The testing sequence for each test date was as follows: First, an initial, unrecorded 40 mph skid test run was conducted over the (dry) test section. (Beginning February 10, 1975, this initial run was also recorded.) Then, recorded test runs were conducted on a continuous basis, at an average rate per vehicle of one skid test every two minutes. The vehicles' electronics were re-zeroed prior to the first recorded run and at random times throughout the test series. This was done in order to test the effect of re-zeroing on the resulting force traces. Test water was allowed to accumulate on the test area as much as the 2% ± superelevation would allow. The effects of water accumulation gradually reduced the skid number of the test surfaces until steady-state conditions were achieved after 3 to 5 runs on test section ALPHA. The right test wheel was used exclusively on both machines, primarily with ribbed tires (ASTM E-249). A few tests were conducted with a smooth tire, primarily to observe for unusual wear or damage in that tread configuration. Each skid test consisted of a standard 4 second ± cycle.

A traffic cone marker placed 110 ± feet upstream of the first galvanized sheet was used by the vehicle operator to start the test cycle. By beginning each test cycle the same distance from the experimental surfaces, the effects of differential tire heat buildup between tests were minimized. The operators, however, could not start the test cycle closer than 20 feet ± from the marker, due to their necessary preoccupation with accurate speed and direction of their vehicles. (A simple, portable, automatic-start system can be easily designed and incorporated into the testing procedure to improve accuracy of timing and relieve the operators from this additional responsibility.)

A standard skid test cycle beginning at the marker resulted in actual locked-tire skid lengths of 160 feet ± at 40 mph using the Law machine. This included two sections of the existing dense-graded asphalt concrete surface, one 50 feet ± long "upstream" and one 50 feet ± long "downstream" of the metal surfaces. The length of the test cycle of the Soiltest machine was increased slightly in order to roughly match the actual locked-tire skid length of the Law vehicle, but this was done after the January 27, 1975 testing was completed.

Initial skid runs conducted on test section ALPHA revealed that the two galvanized steel sheets were serving their dual purpose of acting as a test surface and of indicating the beginning and end of the expanded metal surfaces very well. Of the five expanded metal sheets, however, the first and last sheets (Nos. 2 and 6 in Fig. 3) revealed a strong tendency to shear small strips of rubber from the test tires (a typical strip measured approximately 3 inches in length and 1/16th inch in diameter). The center three sheets did not cause tire damage. Careful inspection revealed thin knife-edged projections caused by the manufacturing process were much more prevalent at the two outer sheets (Nos. 2 and 6) than in the center three. The last sheet (No. 6) was also known to have been obtained from a different supplier, and welded "wrong-side-up" to the other four sheets. This latter fact was tolerated because it was not expected to significantly influence test results, and timing the placement of the test surface to the availability of skid test vehicles was critical because of wet weather and associated corrosion problems.

To cure the tire-shearing tendency of the expanded metal, sheets No. 2, 3, and 6 were sandblasted prior to further skid testing. A steel sheet underneath the open mesh was used to protect the AC surface from the sandblasting. The next skid test runs, conducted on January 27, 1975, revealed that sandblasting had entirely eliminated the tire-shearing problem. It had also raised the coefficient of friction of the sandblasted screens. To further test this tendency, the remaining (3rd and 4th) sheets were also sandblasted. The next skid runs, conducted on January 30, 1975 and February 10, 1975 revealed a 20% increase in coefficient of friction for these two recently sandblasted screens.

As a result of the experience gained from test section ALPHA, the Expanded Metal Flattened sheets used in test section BETA were sandblasted prior to installation. After installation, skid test runs were conducted over this section in the same manner as on test section ALPHA.

4. Data Analysis

Skid test raw data consist of chart recordings of the horizontal friction force, which must be visually interpreted. The "zig-zag" nature of these force traces poses a certain difficulty in accurate interpretation, and the resulting values may be influenced by the interpreters' bias. To ascertain the effect, if any, of such a bias, one inexperienced and two experienced interpreters were given the same chart recordings of 25 consecutive runs from the Law machine on test section ALPHA. They were asked to interpret the values of the horizontal friction force corresponding to each test surface. The set of values obtained from each interpreter was then averaged for each test surface, and converted to an equivalent skid number. Table 2 presents the resulting skid numbers obtained, and indicates that the maximum difference between interpreted average values was 0.9 skid numbers, which is better than the skid test machine's precision.

Table 2. Interpretation of 25 Chart Recordings

Surface	Average Skid Number: Experienced Interpreter 1	Inexperienced Interpreter	Experienced Interpreter 2
Upstream DGAC	65.2	65.5	65.8
Exp. Metal Sandblasted	55.5	55.0	55.7
Exp. Metal	38.0	37.9	38.2
Downstream DGAC	66.6	67.1	67.5

Raw test data from every recorded run was interpreted and horizontal friction force values were established for each surface type on test sections ALPHA and BETA. The average test speed for each run was also established from the raw data. (For complete listing of horizontal friction force values and test speeds see Appendix B.)

Figures 6, 7, and 8 present the record of all skid test runs, and the frictional force obtained in each run from each test surface, including the "control" AC surfaces "upstream" and "downstream" of the metal.

FIG. 6 RECORD OF SKID TEST RUNS

TEST SECTION ALPHA

"Law" Tester at 40 mph

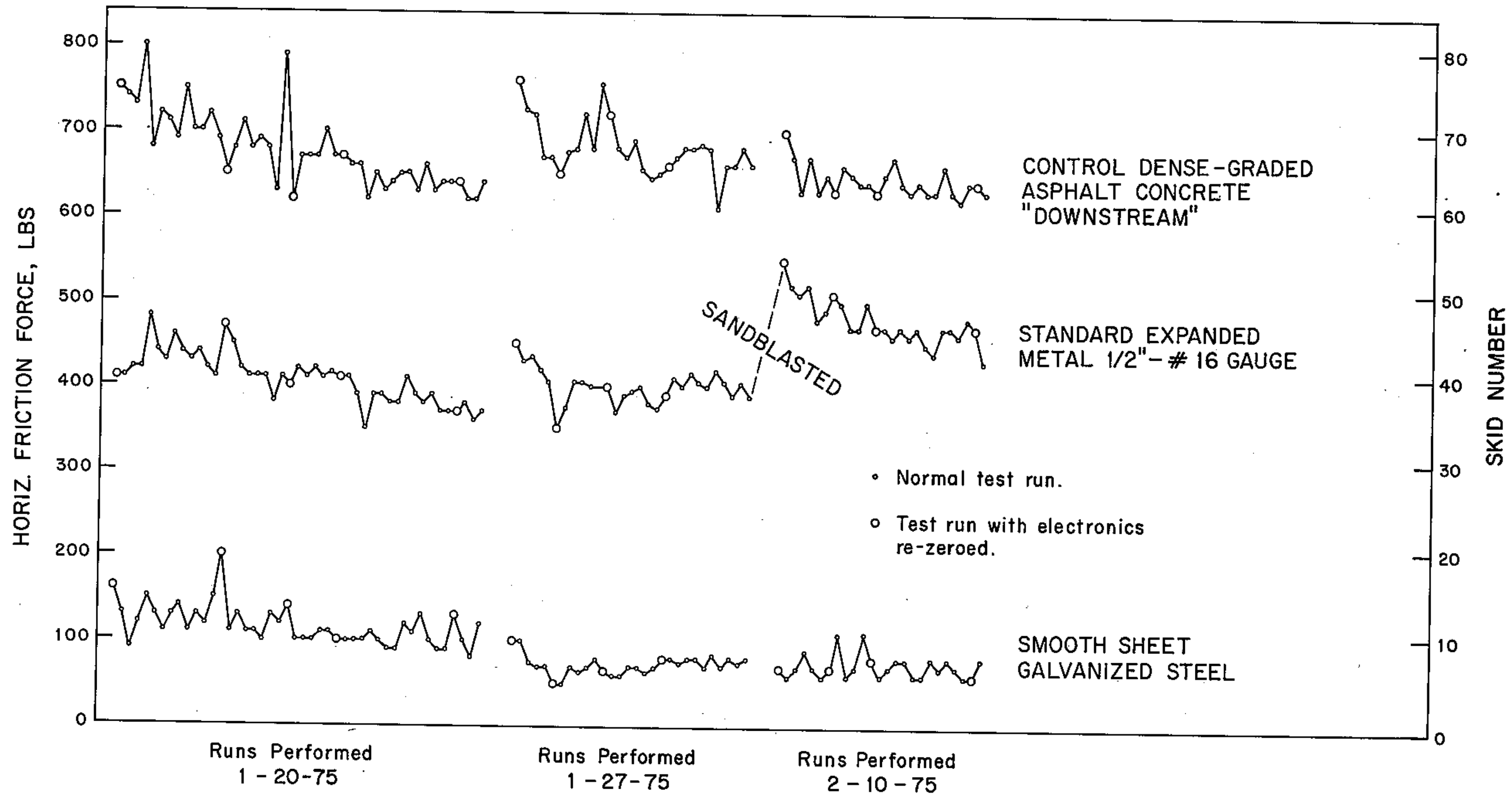


FIG. 7 RECORD OF SKID TEST RUNS

TEST SECTION ALPHA

"Soiltest" Tester at 40 mph

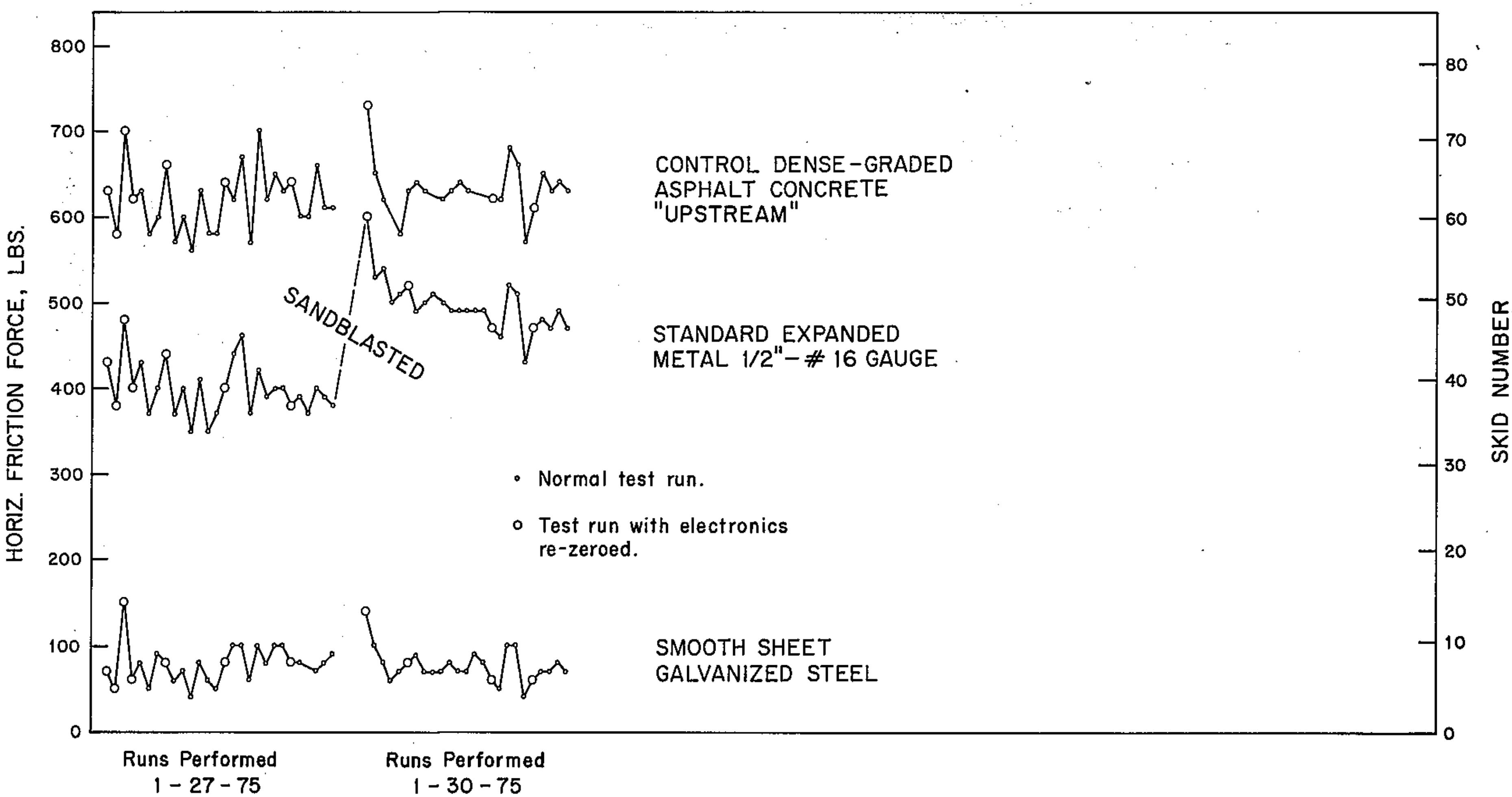
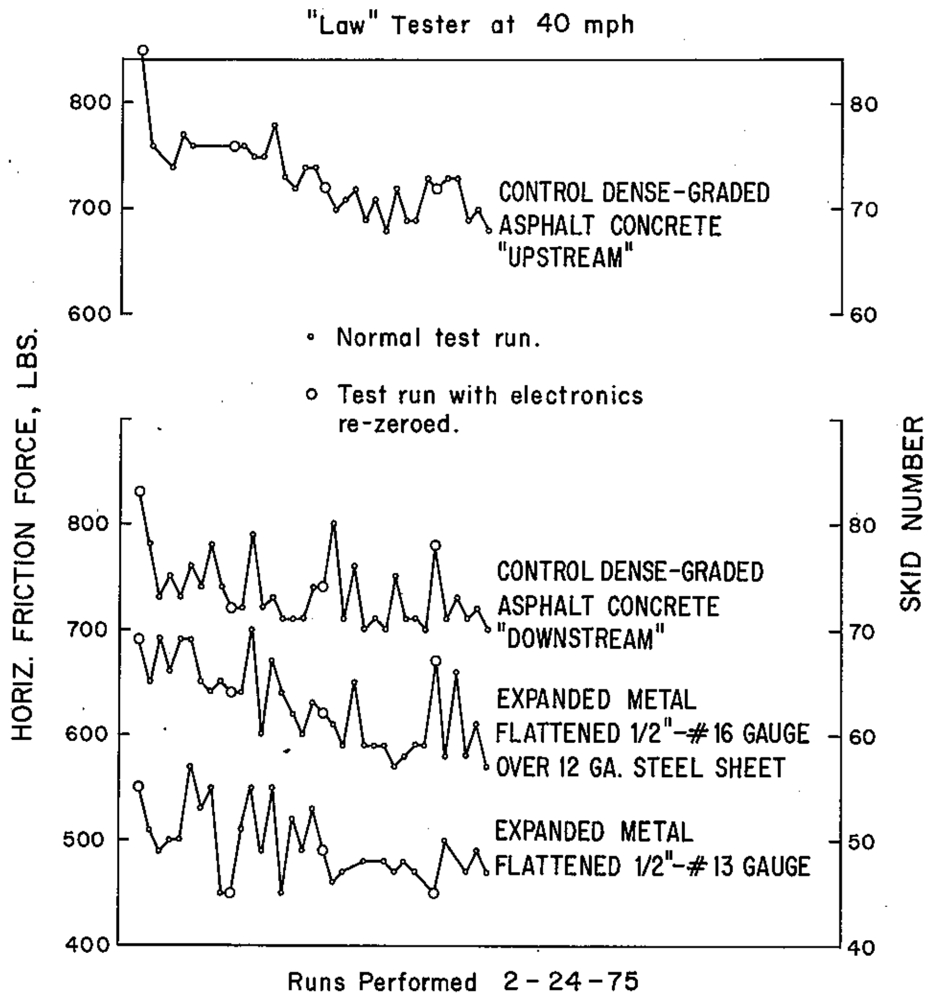
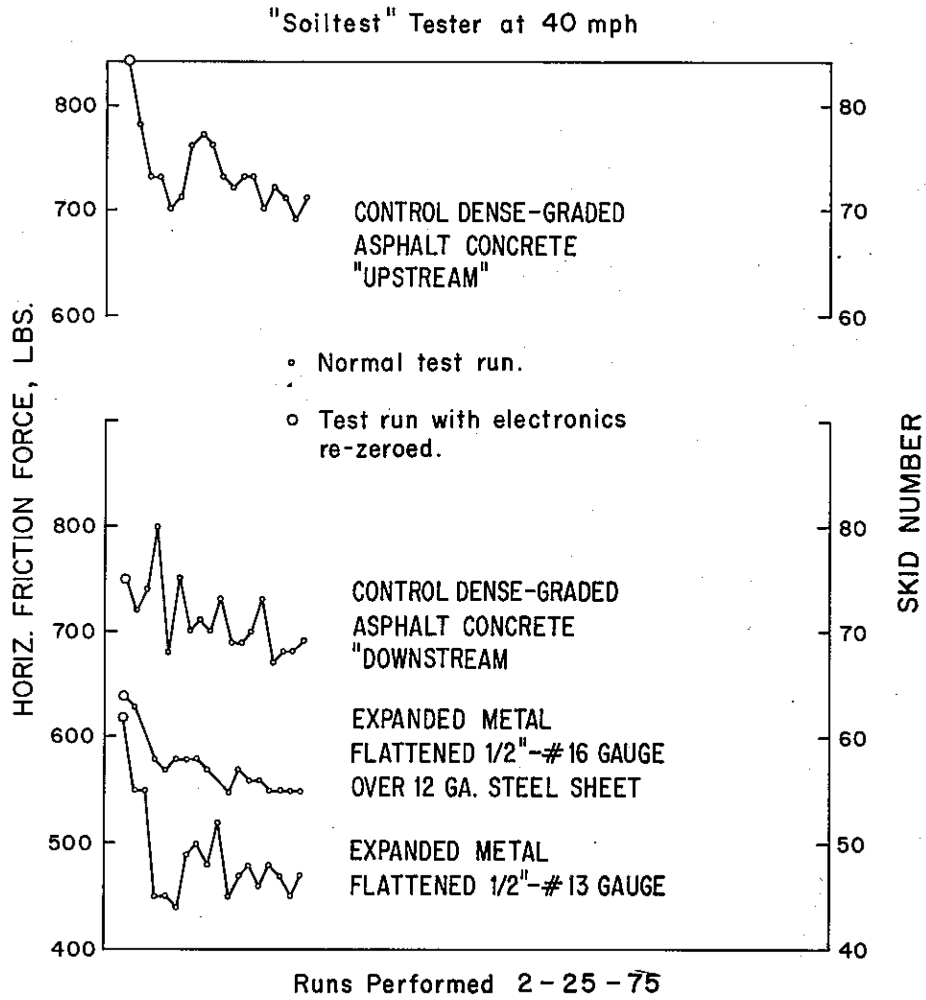


FIG. 8 RECORD OF SKID TEST RUNS

TEST SECTION BETA





A statistical analysis was performed on the resulting data to obtain the mean and standard deviation of values from each surface. Data recorded on each test date was analyzed separately, and the first five recorded runs over each test section were excluded from analysis, in order to compare steady-state conditions. Tables 3 and 4 present the summary of results from the statistical analysis for the 40 mph runs. Tables 5, 6, and 8 present the summaries of results from test runs at speeds other than 40 mph; Table 7 presents the results from test runs using a smooth tire. (Horizontal force values have been converted to skid numbers.)

Table 3. Average 40 mph Skid Numbers ± Std. Deviation of Test Section ALPHA

Date	Machine	No. of Runs	Avg. Speed	SKID NUMBER (40 mph) Rib Tire Upstream DGAC	Exp. Metal #2 & #3	Exp. Metal #4 & #5	Smooth Galv. Steel	Downstream DGAC
1-20-75	Law	40	40.2	65.2±3.3	-	38.8±2.6	10.6±2.0	65.9±3.5
1-27-75	Law	24	40.0	65.2±2.6	*55.4±2.0	37.8±1.4	6.5±0.9	66.6±2.7
"	Soiltest	28	39.6	62.1±3.4	*54.2±2.4	38.8±2.9	7.3±2.1	64.1±3.9
1-30-75	Soiltest	20	41.0	63.5±2.2	*52.4±2.0	*47.9±2.0	6.8±1.4	62.1±2.2
2-10-75	Law	20	40.0	63.2±1.4	*51.8±1.8	*45.4±1.8	6.8±1.4	62.9±1.2
	Average		40.1	64.0	53.6	38.5/*46.6	8.0	64.6

*Values obtained after sandblasting.

The values in Table 3 indicate that Skid Numbers obtained from the Expanded Metal and Smooth Metal were as repeatable as the "control" conventional dense-graded AC pavement. The trend toward lessening values as the testing progressed is difficult to assess with confidence, as the maximum change in the value of any surface was less than 2 standard deviations. Assuming this trend is legitimate, a plausible explanation is the "polishing" of the AC and galvanized surfaces, and progressive corrosion of the microtexture of the expanded metal.

Table 4. Average 40 mph Skid Numbers ± Std. Deviation of Test Section BETA

				SKID NUMBER (40 mph) Rib Tire			
Date	Machine	No. of Runs	Avg. Speed	Upstream DGAC	Exp.Metal Flattened	Exp.Met.Flat. Over Steel Sheet	Downstream DGAC
2-24-75	Law	30	39.7	71.5±2.5	47.7±3.3	58.6±3.2	72.4±2.6
2-25-75	Soiltest	13	40*	73.9±2.2	46.6±2.0	56.0±1.2	71.2±2.1
	Average			72.2	47.4	57.8	72.0

*Assumed ± 2 mph; speed trace not recorded.

The values in Table 4 indicate that Skid Numbers obtained from the Expanded Metal Flattened are as repeatable as the "control" conventional dense-graded AC pavement.

Table 5. Average 30 mph Skid Numbers of Test Section ALPHA

Date	Machine	No. of Runs	Avg.Speed	SKID NUMBER (30 mph) Rib Tire				
				Upstream DGAC	Exp.Metal #2 & #3	Exp.Metal #4 & #5	Smooth Galv.Steel	Downstream DGAC
1-27-75	Law	1	30.0	71.3	58.7	41.4	7.4	-
"	Soiltest	1	30.0	-	60.0	45.1	9.3	-
1-30-75	Soiltest	10	31.0	67.5	54.7	47.0	7.4	64.4
"	Law	5	30.6	66.2	54.4	47.0	7.4	67.9

All values obtained after sandblasting expanded metal surfaces.

Table 6. Average 50 mph Skid Numbers of Test Section ALPHA

				SKID NUMBER (50 mph) Rib Tire				
Date	Machine	No. of Runs	Avg. Speed	Upstream DGAC	Exp. Metal #2 & #3	Exp. Metal #4 & #5	Smooth Galv. Steel	Downstream DGAC
2-10-75	Law	5	49.6	60.4	47.8	41.6	6.1	58.5

Table 7. Average Smooth Tire Skid Numbers of Test Section ALPHA

				SKID NUMBERS (40 & 50 mph) Smooth Tire				
Date	Machine	No. of Runs	Avg. Speed	Upstream DGAC	Exp. Metal #2 & #3	Exp. Metal #4 & #5	Smooth Galv. Steel	Downstream DGAC
1-30-75	Soiltest	10	41.7	61.3	48.8	43.6	4.7	59.8
"	"	1	50.0	56.8	46.2	42.0	4.6	55.7

Table 8. Average 30 & 50 mph Skid Numbers of Test Section BETA

Date	Machine	No. of Runs	Avg. Speed	SKID NUMBER (30 & 50 mph) Rib Tire			
				Upstream DGAC	Exp.Metal Flattened	Exp.Met.Flat. Over Steel Sheet	Downstream DGAC
2-24-75	Law	5	30.0	73.7	50.9	57.5	75.0
"	"	5	48.2	66.7	-	53.1	68.2

Skid test runs performed with the Law machine on February 10, 1975 and February 24, 1975 were used to determine the skid number/speed gradient of the various surfaces of test sections ALPHA and BETA. The results are presented in Tables 9 and 10.

Table 9. Skid No. Gradients of Test Section ALPHA

	GRADIENT				
Speeds mph	Upstream DGAC	Exp.Metal #2 & #3	Exp.Metal #4 & #5	Smooth Galv.Steel	Downstream DGAC
30.6-40.0	.320	.267	.167	.065	.527
30.6-49.6	.309	.344	.287	.069	.494
40.0-49.6	.298	.420	.404	.073	.461

Table 10. Skid No. Gradients of Test Section BETA

	GRADIENT			
Speeds mph	Upstream DGAC	Exp.Metal Flattened	Exp.Metal Flat. Over Steel Sheet	Downstream DGAC
30.0-39.7	.227	.330	-.113	.268
30.0-48.2	.385	-	.242	.374
39.7-48.2	.565	-	.647	.494

The gradient values indicate that the Standard Expanded Metal surfaces have similar characteristics with the control dense-graded AC. Data from the Expanded Metal Flattened indicate unusual gradient characteristics. The flat gradients of the smooth galvanized steel may be due to tires fully hydroplaning at the 30 to 50 mph speed range. Similar gradients have been noted on bleeding AC pavements. In general, gradient values are considered inconclusive due to the limited test data at speeds other than 40 mph.

5. Field Observations

Visual observation of both test sections indicated that no apparent change occurred in any surface due to the testing. Familiar dark skid tire marks were visible on the AC pavement, but no evidence of polishing or ravelling was noticed.

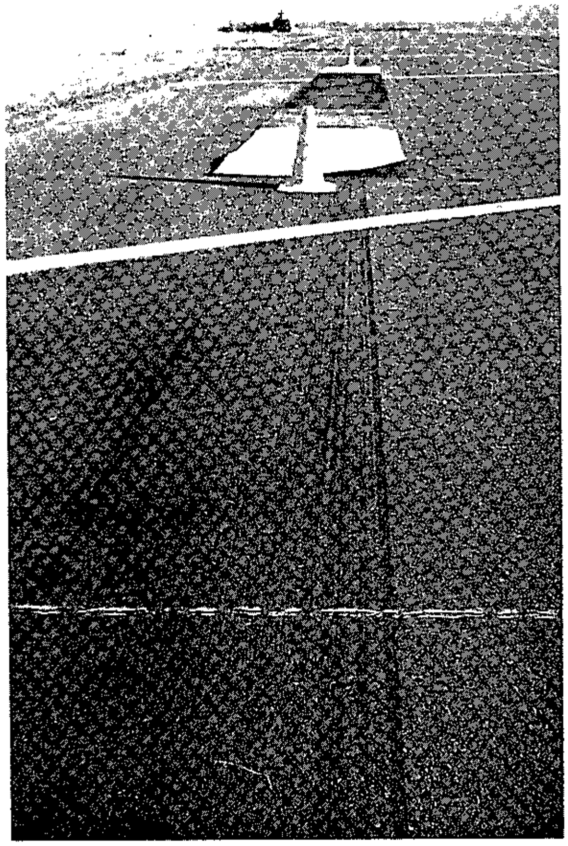


Fig. 9 Skid marks on "downstream" DGAC at Test Section ALPHA after test series were completed. The distortion of the trailing galvanized sheet was caused by high winds and the omission of anchors at the trailing ends. (This occurred after the testing was completed.)

Test tires examined after each series of test runs showed no unusual wear. Several tires were used, having been worn to various degrees in previous routine testing. As tires are considered within ASTM specifications provided they have a minimum tread depth, this depth was not measured on each tire, except for checking that they met specs.

6. Observing Effect of Tire Unbalance

Incorporated in the observation of one series of test runs (February 24, 1975) was a brief study to ascertain if a partly worn test tire has a tendency to "lock up" and skid with favorite spots in its perimeter (a possible effect of severe dynamic unbalance). A partially worn test tire was used for runs on Test Section BETA. The sidewalls of this tire were marked at four points, each 90° apart, with the numbers 1, 2, 3, and 4. As the skidding tire passed the test area, the observer noted the location of that portion of the tire actually in contact with the ground, and recorded this location, e.g., "...run No. 13, tire location 2.7". Accurate observation and estimation to within one tenth of each 90° segment was surprisingly easy.

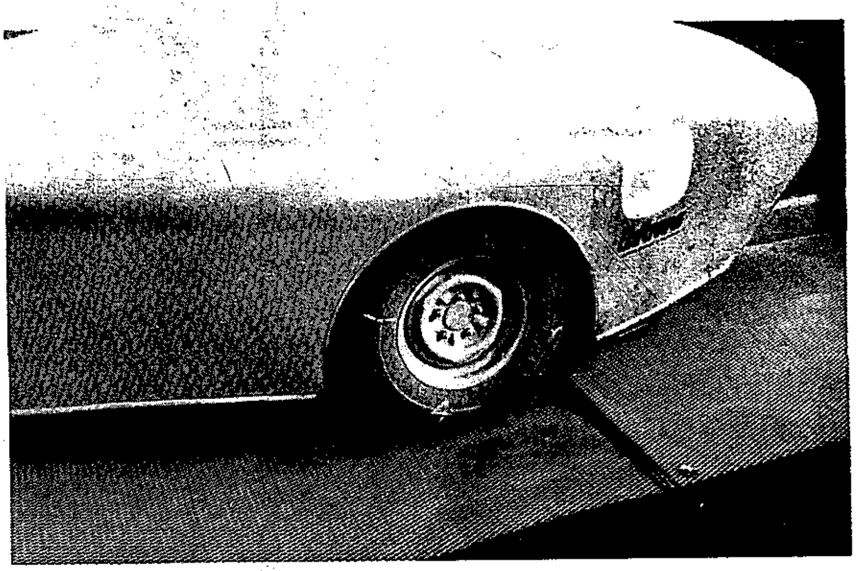


Fig. 10. "Law" trailer showing test tire marked at four points.

Figure 11 is a dot frequency graph of the result of 38 runs observed, indicating that, although some areas skidded more often than others, the results were inconclusive due to the small sample size. Skid numbers from the tire areas which skidded 3 or more times did not reveal a trend toward increasing or decreasing frictional values.

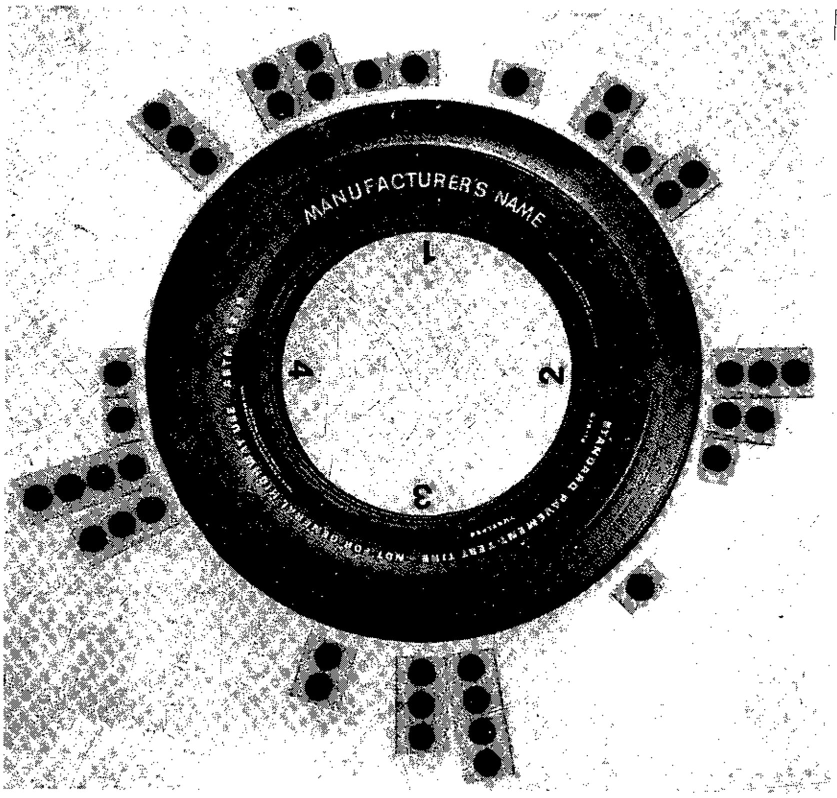


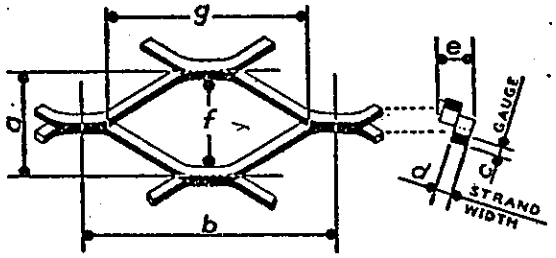
Fig. 11 Dot frequency graph of skid areas on test tire.

REFERENCES

"Metals Stock List," Ducommun Metals & Supply Co., 1973

DUCOMMUN METALS & SUPPLY CO.

STANDARD EXPANDED METALS



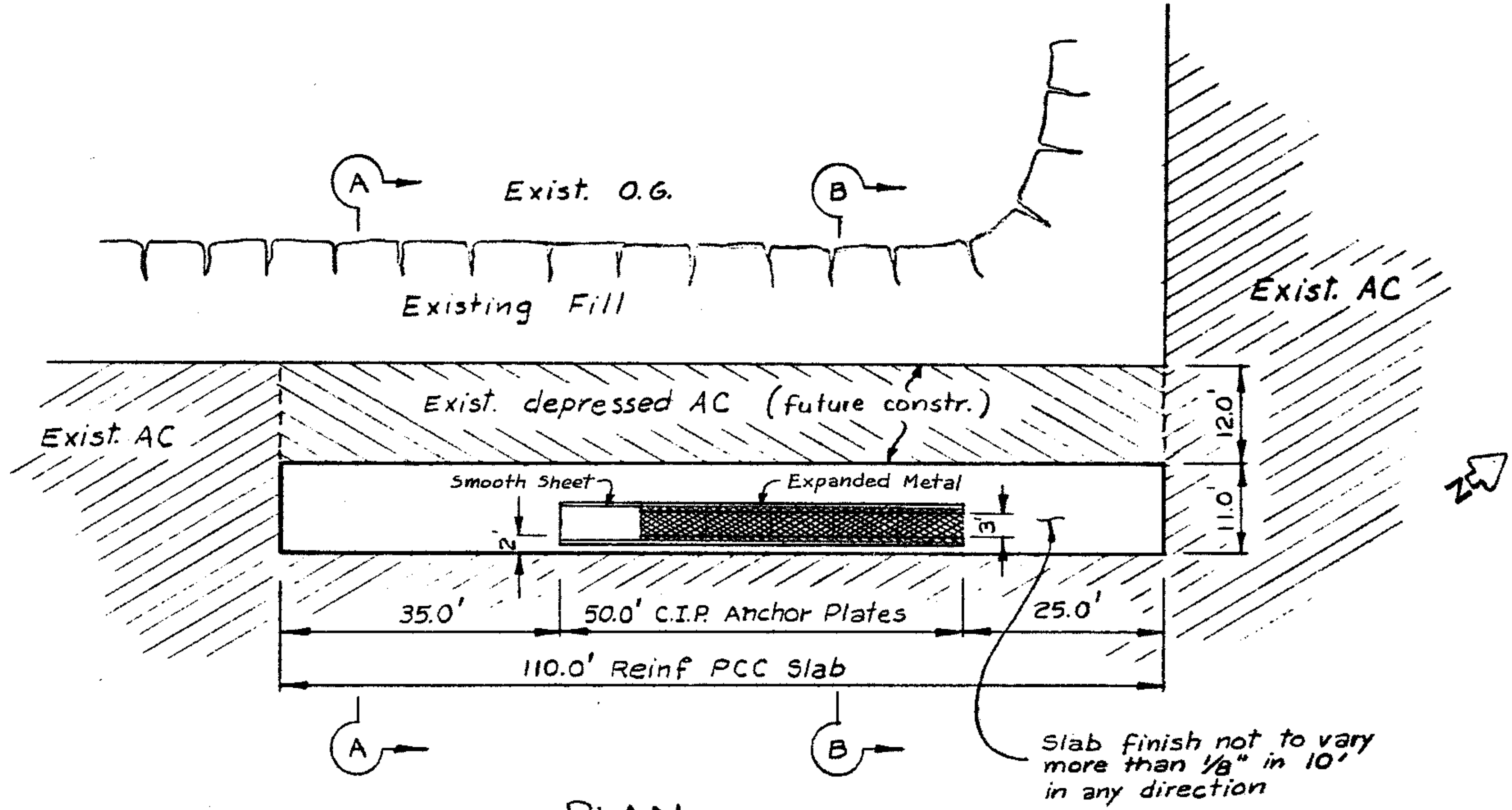
Expanded Metal is a continuous fabric of uniformly shaped diamond meshes, cut and expanded from sheet stock, and made in a variety of gauges and sizes. The meshes are free from mechanical joints and are easily cleaned. When used for window guards, partitions for stockrooms, workrooms, toolrooms, lockers, etc., they furnish security against theft, also freely admit light and air.

Size In. and Style No.	Width and Length Inches	Est. Lbs. Sq. Ft.	Diamond Size Dec. In. a x b	Opening Size Dec. In. f x g	Overall Thick. Dec. In. e	Strand Dec. In. c x d
			CARBON STEEL			
¼-No. 20	48x96	.86	.25x1.0	.167x.747	.124	.036x.073
¼-No. 18	48x96	1.14	.25x1.0	.155x.703	.125	.048x.073
½-No. 20	36x96 48x96	.43	.462x1.2	.400x.968	.124	.036x.066
½-No. 18	48x96 72x96	.70	.462x1.2	.392x.920	.155	.048x.081
½-No. 16	48x96 48x120 72x96	.84	.462x1.2	.375x.906	.157	.060x.078
½-No. 13	48x96 72x96	1.47	.462x1.2	.335x.826	.182	.090x.091
¾-No. 16	36x96 48x96 48x120 72x96	.50	.923x2.0	.844x1.692	.186	.060x.092
¾-No. 13	48x96 48x120 72x96 72x120	.80	.923x2.0	.812x1.635	.205	.090x.098
¾-No. 10	48x96 72x96	1.20	.923x2.0	.786x1.592	.282	.090x.148
¾-No. 9	48x96 48x120 48x144 72x96 72x120 72x144	1.80	.923x2.0	.740x1.514	.300	.134x.148
1-No. 16	48x96	.44	1.00x2.4	.924x1.948	.182	.060x.189
1½-No. 16	48x96	.40	1.33x3.0	1.253x2.608	.211	.060x.107

NOTE—Style Designation: First number represents nominal width of diamond. Second number is the approximate gauge of plate before expanding, except No. 10 is from approximately No. 13 gauge plate.

(Continued on next page)

APPENDIX A - PLANS OF PROPOSED SKID AREA



PLAN

SCALE 1" = 20'

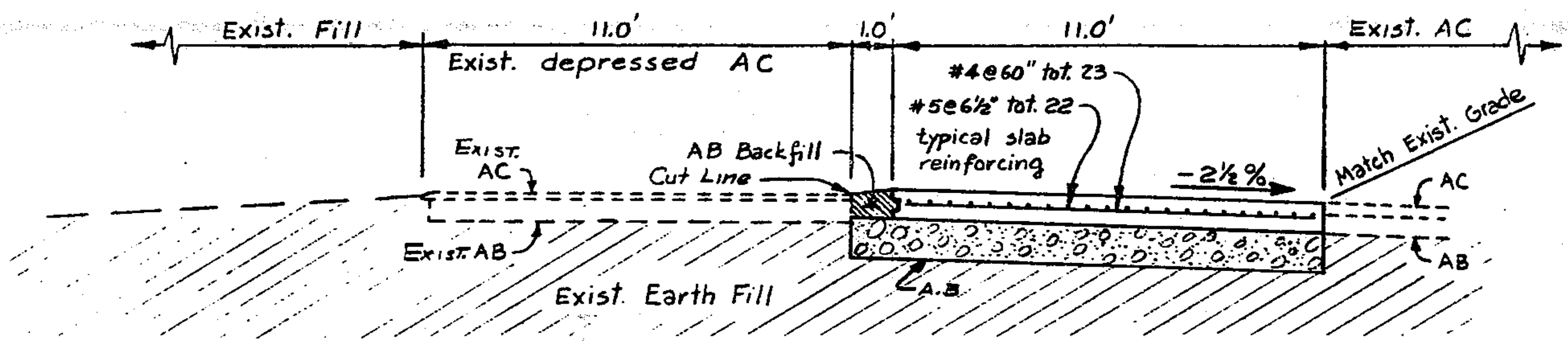
For typical sections A-A and B-B see Sheet 2 of 3

For anchor plate details see Sheet 3 of 3

APPROX. QUANTITIES

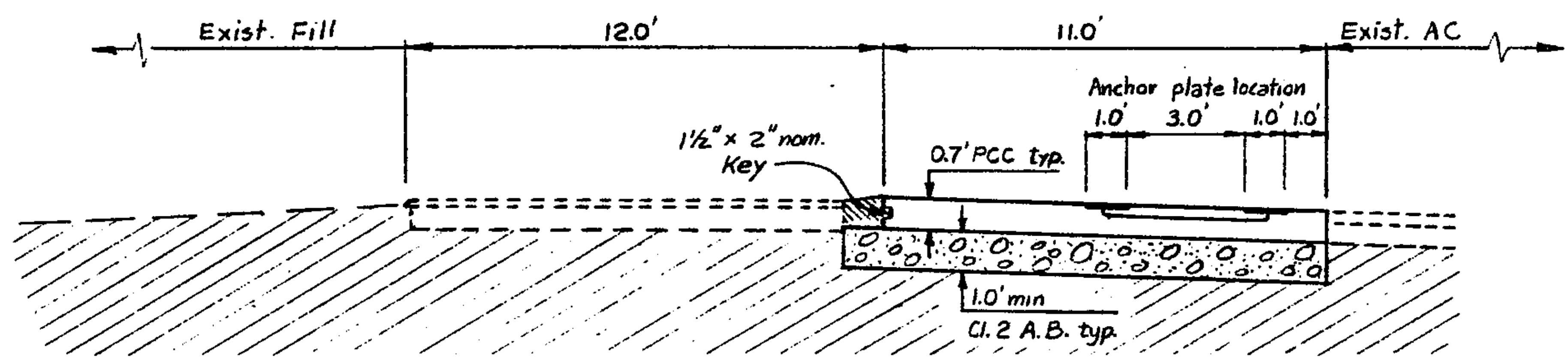
PCC 5½ sacks/Cu.Yd	32 CU.YD.
Bar Reinf. Steel	2500 LBS
Miscellaneous Metal	1700 LBS
Aggregate Base Class 2	52 CU.YD
Remove exist AC	15 CU.YD
Remove exist AB & Soil	68 CU.YD

APPENDIX A - PLANS OF PROPOSED SKID AREA



TYPICAL SECTION A-A

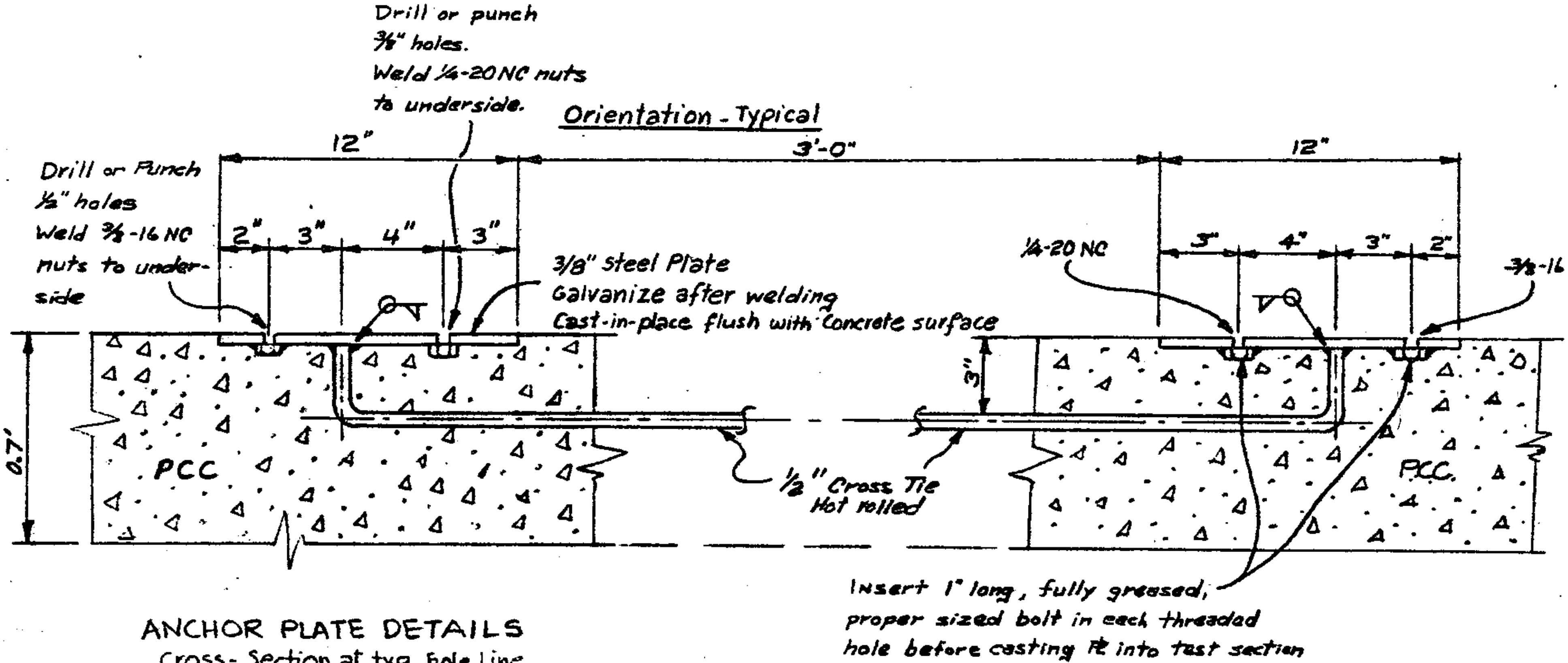
SCALE 1" = 4'



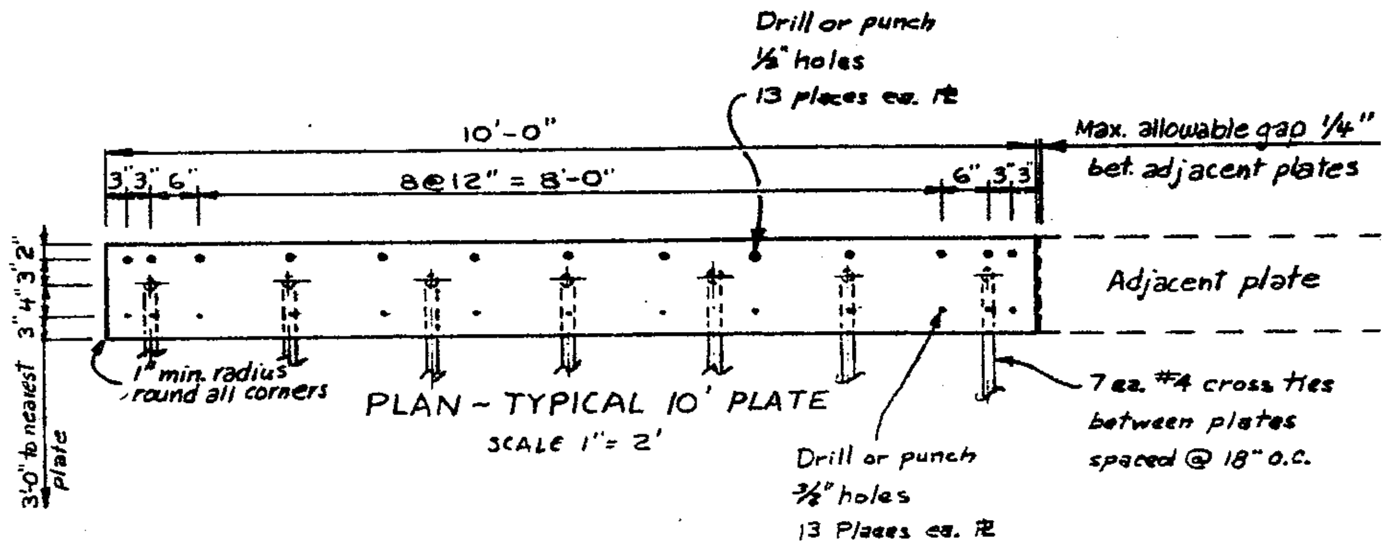
TYPICAL SECTION B-B

SCALE 1" = 4'

APPENDIX A - PLANS OF PROPOSED SKID AREA



ANCHOR PLATE DETAILS
Cross-Section at typ. Hole Line
scale 1" = 6"



PLAN - TYPICAL 10' PLATE
SCALE 1" = 2'

APPENDIX B
SKID TEST DATA: PROPOSED STANDARD SURFACES
TEST SECTION ALPHA

Test Date :	1-20-75	Test Tire	Time :	13:25 – 15:00
Test Vehicle:	LAW	RIB	Air Temp.:	48°F
Operator :	G. Stucky		Rel. Hum.:	Not Measured (Foggy)
Observer :	J. Apostolos		Wind :	Calm

Continuous testing - 4 test runs made but not recorded between runs 29 & 30

RUN NO.	HORIZONTAL FRICTION FORCE, LBS.					TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXP. METAL 2	EXP. METAL 3, 4, & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC		
1	800		410	160	750	39	← ZERO ADJUST ← Dry surface
2	750	Unreadable	410	130	740	40	Throughout Testing:
3	–	trace due	420	90	730	40	Considerable
4	720	to excessive	420	120	800	40	amounts of
5	–	amplitude	480	150	680	40	test tire rubber
6	700	of oscillations	440	130	720	40	being shaved-off
7	710		430	110	710	40	by Exp. Metal
8	–		460	130	690	40	2 & 6.
9	700		440	140	750	40	No rubber was
10	740		430	110	700	41	shaved-off by
11	690		440	130	700	40	Exp. Metal 3,4,or 5
12	690		420	120	720	40	
13	730		410	150	690	40	
14	730		470	200	650	39	← ZERO ADJUST.
15	710		450	110	680	40	
16	690		420	130	710	41	
17	660		410	110	680	40	
18	660		410	110	690	41	
19	660		410	100	680	40	
20	640		380	130	630	40	
21	650		410	120	790	40	
22	660		400	140	620	40	← ZERO ADJUST.
23	670		420	100	670	40	
24	730		410	100	670	40	
25	650		420	100	670	40	
26	660		410	110	700	40	
27	670		415	110	670	41	
28	670		410	100	670	40	
29	660		410	100	660	41	
30	670		390	100	660	40	← ZERO ADJUST.
31	610		350	100	620	41	
32	630		390	110	650	40	
33	660		390	100	630	40	
34	630		380	90	640	40	
35	630		380	90	650	40	

Continued on next page

APPENDIX B

SKID TEST DATA: PROPOSED STANDARD SURFACES
TEST SECTION ALPHA

Test Date : 1-20-75
Test Vehicle : LAW

RUN NO.	HORIZONTAL FRICTION FORCE, LBS.					TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXP. METAL 2	EXP. METAL 3, 4, & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC		
36	630		410	120	650	40	
37	630		390	110	630	40	
38	630		380	130	660	41	
39	630		390	100	630	41	
40	640		370	90	640	40	
41	640		370	90	640	40	
42	620		370	130	640	40	← ZERO ADJUST.
43	620		380	100	620	40	
44	610		360	80	620	40	
45	620		370	120	640	40	

APPENDIX B
SKID TEST DATA: PROPOSED STANDARD SURFACES
TEST SECTION: ALPHA

Test Date: 1-27-75 | Test Tire: RIB | Time: 09:45 - 11:00
Test Vehicle: LAW | Air Temp: 48° steady
Operator: G. Stucky | Rel. Hum.: 49% - 51%
Observer: J. Apostolos | Wind: N 15 MPH

Continuous testing ~ alternating with Soiltest Skid Tester.

RUN NO.	HORIZONTAL FRICTION FORCE, LBS. UPSTREAM DGAC	EXP. METAL 2 & 3	EXP. METAL 4 & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC	TEST SPEED MPH	REMARKS
1	790	685	450	100	760	40	← ZERO ADJUST. ← Dry Surface
2	690	705	430	100	725	40	
3	660	690	435	75	720	40	
4	630	675	420	70	670	40	
5	720	670	405	70	670	40	
6	625	540	350	50	650	40	← ZERO ADJUST
7	680	605	375	50	675	40	
8	660	585	405	70	680	39	
9	700	590	405	65	720	40	
10	635	580	400	70	680	40	
11	730	615	400	80	755	40	
12	720	585	400	65	720	40	← ZERO ADJUST.
13	670	550	370	60	680	41	
14	655	565	390	60	670	40	
15	660	570	395	70	690	40	
16	660	565	400	70	655	40	
17	640	560	380	65	645	40	
18	635	555	375	70	650	40	
19	670	570	390	80	–	40	← ZERO ADJUST.
20	720	600	430	80	–	30	
21	680	550	410	80	670	40	
22	645	535	400	75	680	40	
23	640	565	415	80	680	40	
24	660	565	405	80	685	40	
25	680	575	400	70	680	40	
26	695	600	420	85	610	40	
27	640	560	405	70	660	40	
28	630	560	390	80	660	40	
29	640	545	405	75	680	40	
30	635	535	390	80	660	40	

APPENDIX B

SKID TEST DATA : PROPOSED STANDARD SURFACES
TEST SECTION ALPHA

Test Date : 1-27-75
Test Vehicle : SOILTEST
Operator : L. Batham
Observer : J. Apostolos

Test Tire: RIB

Time : 09:45 - 11:00
Air Temp. : 48°F Steady
Rel. Hum. : 49 % - 51 %
Wind : N 15 mph

Continuous testing ~ alternating with LAW Skid Tester

RUN NO.	HORIZONTAL FRICTION FORCE, LBS.					TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXP. METAL 2 & 3	EXP. METAL 4 & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC		
1	630	570	430	770	660	42	← ZERO ADJUST. Wet surf. due to 5 runs with LAW
2	580	570	380	50	–	40	← ZERO ADJUST.
3	700	610	480	150	700	40	← ZERO ADJUST.
4	620	520	400	60	680	40	← ZERO ADJUST.
5	630	580	430	80	–	38	
6	580	540	370	50	–	40	
7	600	550	400	90	650	41	
8	660	580	440	80	670	40	← ZERO ADJUST.
9	570	540	370	60	–	40	
10	600	550	400	70	650	40	
11	560	520	350	40	550	39	
12	630	560	410	80	600	40	
13	580	510	350	60	–	40	
14	580	510	370	50	580	40	
15	640	550	400	80	630	40	← ZERO ADJUST.
16	620	560	440	100	–	40	
17	–	600	460	100	–	30	← NOTE 30 MPH
18	670	570	460	100	700	40	
19	570	500	370	60	580	40	
20	700	560	420	100	650	40	
21	620	530	390	80	630	40	
22	650	560	400	100	–	38	
23	630	550	400	100	600	39	
24	640	520	380	80	–	38	← ZERO ADJUST.
25	600	540	390	80	630	38	
26	600	520	370	–	–	39	
27	660	560	400	70	–	40	
28	610	520	390	80	670	39	
29	610	540	380	90	650	39	

APPENDIX B

SKID TEST DATA : PROPOSED STANDARD SURFACES
TEST SECTION ALPHA

Test Date : 1-30-75
Test Vehicle : SOILTEST
Operator : L. Batham
Observer : None

Test Tire
Runs 1-35 : RIB
Runs 36-46 : SMOOTH

Time : 14:45
Air Temp : 49°F
Rel. Hum. : 55%
Wind : Calm

Continuous Testing

RUN NO.	HORIZONTAL FRICTION FORCE, LBS					TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXP. METAL 2 & 3	EXP. METAL 4 & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC		
1	730	580	600	140	800	42	← ZERO ADJUST. ← Dry Surface
2	650	550	530	100	670	42	
3	620	530	540	80	650	42	
4	—	530	500	60	640	42	
5	580	540	510	70	640	42	
6	630	540	520	80	650	41	← ZERO ADJUST.
7	640	520	490	90	630	41	
8	630	550	500	70	600	42	
9	—	530	510	70	630	41	
10	620	550	500	70	600	41	
11	630	550	490	80	610	40	
12	640	540	490	70	610	43	
13	630	530	490	70	620	40	
14	—	530	490	90	630	42	
15	—	540	490	80	640	41	
16	—	520	470	60	600	41	← ZERO ADJUST.
17	620	480	460	50	610	40	
18	680	550	520	100	680	40	
19	660	560	510	100	620	40	
20	570	480	430	40	560	40	
21	610	500	470	60	620	41	← ZERO ADJUST.
22	650	520	480	70	620	41	
23	630	530	470	70	610	40	
24	640	520	490	80	630	42	
25	630	540	470	70	610	42	
26	670	530	460	70	620	32	← ZERO ADJUST.
27	660	530	460	70	630	31	
28	660	540	470	60	620	30	
29	—	540	460	70	620	30	
30	—	570	490	90	680	31	
31	660	560	500	90	670	31	← ZERO ADJUST.
32	710	580	500	80	650	31	
33	650	550	470	80	630	31	
34	—	560	490	80	640	32	
35	670	550	480	100	640	31	

Continued on next page

APPENDIX B
SKID TEST DATA : PROPOSED STANDARD SURFACES

Test Date : 1-30-75 Test Tire
Test Vehicle : SOILTEST

Runs 36-46: SMOOTH

RUN NO	HORIZONTAL FRICTION FORCE, LBS.					TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXP. METAL 2 & 3	EXP. METAL 4 & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC		
36	630	550	460	50	600	42	← ZERO ADJUST.
37	620	500	450	40	600	42	
38	610	480	440	50	570	42	
39	610	470	430	40	590	41	
40	600	470	430	40	570	41	
41	610	500	440	60	610	42	← ZERO ADJUST.
42	620	490	450	60	600	42	
43	620	500	440	60	590	42	
44	620	500	460	50	670	42	
45	620	490	450	60	580	41	
46	570	470	430	50	560	50	← NOTE 50 MPH

APPENDIX B

SKID TEST DATA : PROPOSED STANDARD SURFACES

TEST SECTION ALPHA

Test Date	2-10-75	Test Tire		Time	09:30 - 11:00
Test Vehicle	LAW	RIB		Air Temp.	56°F
Operator	G. Stucky			Rel. Hum.	71 %
Observer	None			Wind	S. 5 MPH

Continuous Testing

RUN NO.	HORIZONTAL FRICTION FORCE, LBS					TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXP. METAL 2 & 3	EXP. METAL 4 & 5	SMOOTH GALV. STEEL	DOWNSTREAM DGAC		
1	730	620	550	70	700	40	← ZERO ADJUST. ← Dry surface. Rusty appearance from recent he[illegible] rainstorms
2	670	570	520	60	670	39	
3	650	560	510	70	630	40	
4	640	550	520	90	670	41	
5	650	540	480	70	630	40	
6	680	550	490	60	650	40	
7	680	580	510	70	630	40	← ZERO ADJUST.
8	640	560	500	110	660	39	
9	650	520	470	60	650	40	
10	660	550	470	70	640	40	
11	640	550	500	110	640	40	
12	630	530	470	80	630	40	← ZERO ADJUST.
13	640	530	470	60	650	40	
14	640	540	460	70	670	40	
15	630	530	470	80	640	40	
16	630	530	460	80	630	40	
17	640	560	470	60	640	40	
18	630	500	450	60	630	40	
19	640	520	440	80	630	40	
20	630	510	470	70	660	40	← ZERO ADJUST.
21	640	530	470	80	630	41	
22	—	520	460	70	620	40	
23	650	530	480	60	640	40	
24	—	510	470	60	640	40	
25	630	520	430	80	630	40	
26	700	550	470	70	—	30	← ZERO ADJUST.
27	690	590	510	90	680	30	
28	650	570	520	90	730	30	
29	660	560	470	90	670	32	
30	660	520	460	60	670	31	
31	620	510	450	70	600	49	← ZERO ADJUST.
32	620	490	440	60	600	50	
33	620	500	430	70	610	50	
34	610	490	430	60	590	49	
35	610	480	410	70	590	50	
36	620	570	420	70	630	40	← ZERO ADJUST ← No skid tester water was [illegible]
37	630	540	450	70	620	41	←

APPENDIX B

SKID TEST DATA: PROPOSED STANDARD SURFACES

TEST SECTION BETA

Test Date	2-24-75	Test Tire	RIB	Time	14:30 - 16:40
Test Vehicle	LAW			Air Temp.	67° - 71°F
Operator	G. Stucky			Rel. Hum	62% - 57%
Observer	J. Appostolos			Wind	NW 5 mph

Continuous Testing

RUN NO.	HORIZONTAL FRICTION FORCE, LBS. UPSTREAM DGAC	EXPANDED METAL FLATTENED	EXP. METAL FLAT. OVER STEEL SHEET	DOWNSTREAM DGAC	TEST SPEED MPH	REMARKS
1	850	550	690	830	40	← ZERO ADJUST ← DRY SURFACE
2	760	510	650	780	40	
3	–	490	690	730	39	
4	740	500	660	750	40	
5	770	500	690	730	40	
6	760	570	690	760	39	
7	–	530	650	740	40	
8	–	550	640	780	40	
9	–	450	650	740	39	
10	760	450	640	720	40	← ZERO ADJUST.
11	760	510	640	720	39	
12	750	550	–	790	40	
13	750	490	600	720	40	
14	780	550	670	730	39	
15	730	450	640	710	40	
16	720	520	620	710	40	
17	740	490	600	710	40	
18	740	530	630	740	40	
19	720	490	620	740	40	
20	700	460	610	800	39	← ZERO ADJUST.
21	710	470	590	710	40	
22	720	–	650	760	40	
23	690	480	590	700	40	
24	710	–	590	710	40	
25	680	480	590	700	40	
26	720	470	570	750	40	
27	690	480	580	710	40	
28	690	470	590	710	40	
29	730	–	590	700	40	
30	720	450	670	780	39	← ZERO ADJUST.
31	730	500	590	710	40	
32	730	–	660	730	39	
33	690	470	580	710	40	
34	700	490	610	720	39	
35	680	470	570	700	40	

Continued on next page

APPENDIX B

SKID TEST DATA: PROPOSED STANDARD SURFACES

TEST SECTION BETA

Test Date 2-24-75

Test Vehicle LAW

RUN NO.	HORIZONTAL FRICTION FORCE, LBS.				TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXPANDED METAL FLATTENED	EXP. METAL FLAT. OVER STEEL SHEET	DOWNSTREAM DGAC		
36	660	—	550	680	48	
37	680	—	550	680	48	
38	660	—	540	690	48	
39	710	—	540	710	48	
40	670	—	550	700	49	
41	750	530	580	770	30	← ZERO ADJUST
42	760	500	600	750	30	
43	740	540	590	750	30	
44	700	520	580	740	30	
45	760	530	590	760	30	

APPENDIX B

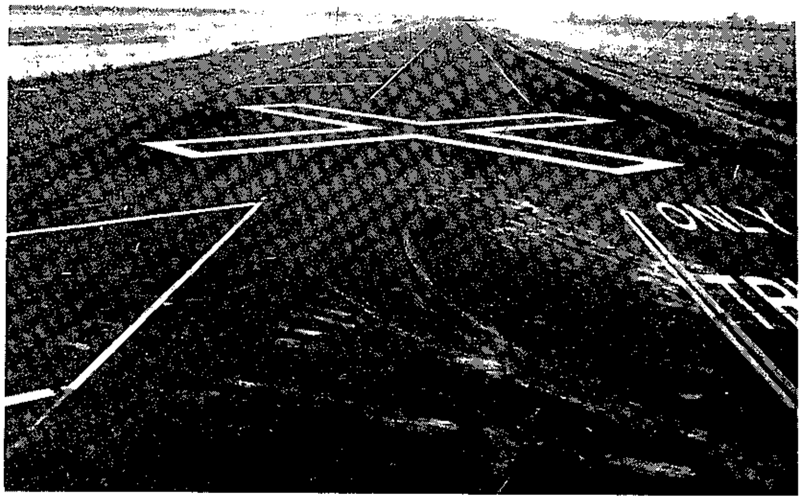
SKID TEST DATA: PROPOSED STANDARD SURFACES
TEST SECTION BETA

Test Date	2-25-75	Test Tire		Time	11:05 - 11:35
Test Vehicle	SOILTEST	RIB		Air Temp.	61° F
Operator	H. Sterner			Rel. Hum.	70%
Observer	J. Apostolos			Wind	Calm

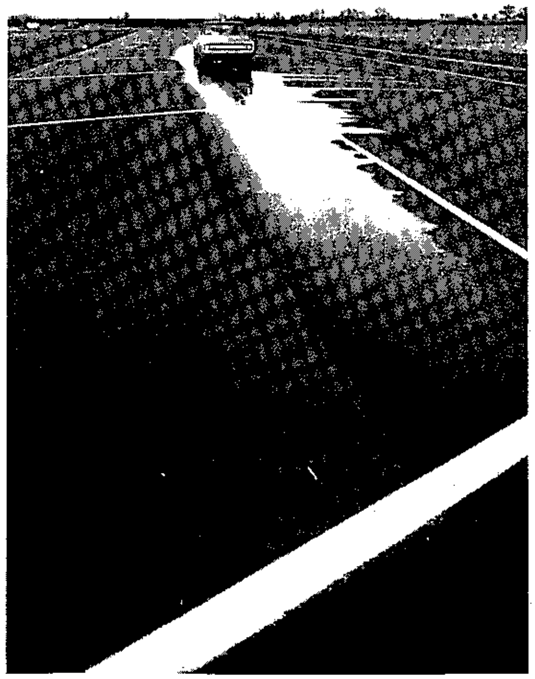
Continuous Testing

RUN NO.	HORIZONTAL FRICTION FORCE, LBS.				TEST SPEED MPH	REMARKS
	UPSTREAM DGAC	EXPANDED METAL FLATTENED	EXP. METAL FLAT. OVER STEEL SHEET	DOWNSTREAM DGAC		
1	840	620	640	750	40 *	← ZERO ADJUST. ← DRY SURFACE
2	780	550	630	720		
3	730	550	680	740		
4	730	450	580	800		
5	700	450	570	680		
6	710	440	580	750		
7	760	490	580	700		
8	770	500	580	710		
9	760	480	570	700		
10	730	520	—	730		
11	720	450	550	690		
12	730	470	570	690		
13	730	480	560	700		
14	700	460	560	730		
15	720	480	550	670		
16	710	470	550	680		
17	690	450	550	680		
18	710	470	550	690		

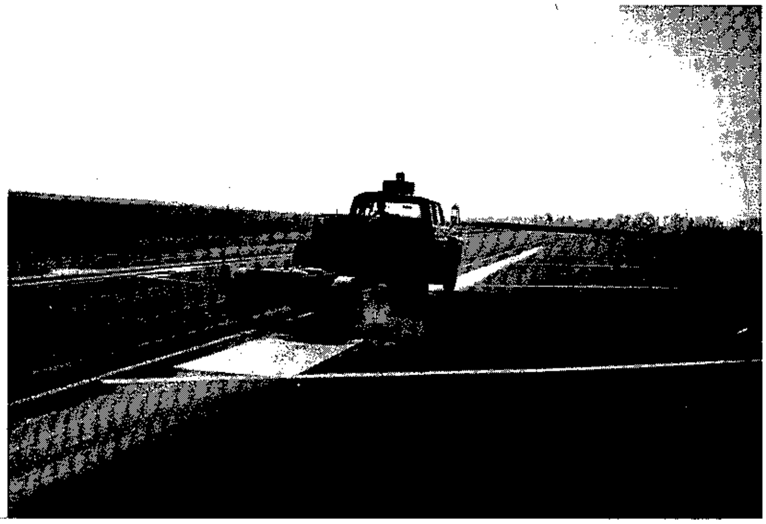
* Speed trace not recorded; all runs made at 40 ± 1 mph.



Dynamic Test Area looking north. "X" on pavement warns aircraft that this is not a landing field (which it resembles).



Typical water accumulation on test surfaces. Law machine is standing on test section BETA. Cross slope is approx. 1 1/2%.



Soiltest machine skid testing at 40 mph on test section BETA.