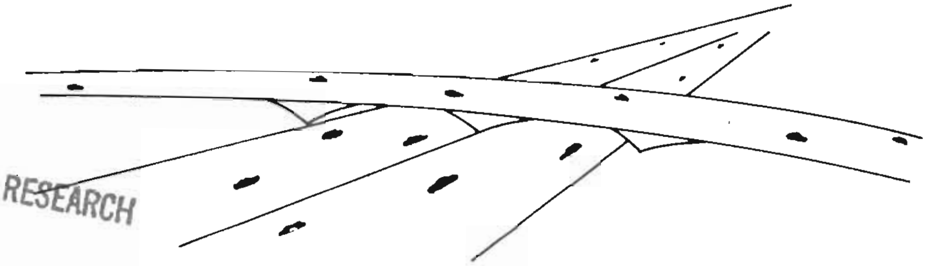


DEPARTMENTAL RESEARCH

Report Number : 126 - 1

FIELD FRICTION PERFORMANCE OF SEVERAL EXPERIMENTAL TEST SECTIONS

TEXAS HIGHWAY DEPARTMENT

FIELD FRICTION PERFORMANCE OF SEVERAL EXPERIMENTAL TEST SECTIONS

by

Jon P. Underwood

Research Report 126-1
A Laboratory and Field Evaluation of the Polishing
Characteristics of Texas Aggregates

Research Study 1-8-68-126

Conducted by
Highway Design Division, Research Section
Texas Highway Department
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

March 1971

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The research reported herein was conducted under the supervision of Mr. John F. Nixon, Engineer of Research, and the general supervision of Mr. Robert L. Lewis, Chief Engineer of Highway Design.

Special thanks are given to Mr. Kenneth Hankins for his hours of consultation and assistance in writing this report.

Thanks is extended to Mr. Brad Hubbard, Mr. Curtis Goss, Mr. Bobby Cannaday, and Mr. Bob Weilder for assistance in the collection and analysis of the data. Acknowledgement is also given to Mr. Richard Tyler and other members of the Research Section, Design Division, for their consultation and help.

ABSTRACT

Aggregate Polishing Characteristics: Field Friction Performance

Project Number : HPR-1(10), 1-8-68-126

Investigators : Underwood, Hankins

Research Agency : Texas Highway Department

Sponsor : Texas Highway Department and
Federal Highway Administration

Date : March 1971

Started : September 1968

Status : Active

Estimated Completion: August 1972

Key Words : Field Aggregate Polish
Locked Wheel Skid Trailer
Aggregate Friction (Field)
Pavement Surface Type

There is an ever increasing awareness of the effect of the coarse aggregate type (used in pavement surfaces) on skid resistance. One phase of this study has been an attempt to study the wear or polish characteristics of coarse aggregates under actual traffic. Experimental sections with various coarse aggregate types have been placed at different locations throughout the state. Friction readings have been obtained at 20 miles per hour and at 50 miles per hour at periodic time intervals with a locked wheel skid test trailer. Two surfaces, Hot Mix Asphaltic Concrete and Surface Treatments were used in these sections.

The purpose of this report is to describe these sections and their results for a period of time.

LIST OF FIGURES

LIST OF TABLES

IMPLEMENTATION

From this phase of Research Study 1-8-68-126 it is recommended that synthetic (lightweight) aggregate be removed from the list of experimental aggregates and be used state-wide for asphaltic concrete pavements. This recommendation is made because, as is discussed later in this report, synthetic (lightweight) aggregate has proven it is superior in skid resistant qualities to all other aggregates studied, and to date has shown good structural qualities.

SUMMARY

The recommendation has been made to implement this phase of the study by removing synthetic (lightweight) aggregate from the list of experimental aggregates. In almost every case lightweight aggregate has shown a superior resistance to polish, regardless of whether it is used in a surface treatment or in a Hot Mix Asphaltic Concrete Surface.

The fine aggregate appears to have an effect on the coefficient, and this is illustrated where the coarse aggregate type has been held constant and the fine aggregate type varied.

Comparing the results of two test sections using the same aggregate type, construction appears to have a definite effect on the initial coefficient of friction.

I. INTRODUCTION

Background

Several attempts have been made throughout past years to determine the relationship of pavement surfacing materials and its skid resistance characteristics. Skid Resistance is defined as:

1. An adhesion between the tire and pavement which is defined by the molecular forces.[1]

2. A deformation between the tire and the pavement which is defined by the energy absorption in the rubber resulting from contact with surface projections.[1]

As traffic rolls over a pavement surface the adhesion and deformation between the tire and the pavement become less, causing a change in skid resistance. This change generally results in a decrease in the coefficient of friction. In the past, attempts have been made to collect a random sample of surfaces with the same material type. Each surface had a different amount of traffic. When studies were made of the polish characteristics of this material, extreme variation in skid resistance was noted. Because of this variance, it was concluded that the only way to study a material was to place a test section and take periodic friction measurements. Therefore, a series of experimental test sections has been constructed using various types of coarse aggregates as part of the pavement surface matrix.

Objectives

The objectives of the investigation reported herein are concerned with determining the "polish" susceptibility of various Texas aggregates under actual traffic.

II. DESCRIPTION OF TEST SECTIONS

Experimental test sections were placed at various locations throughout the state. These sections were placed on Texas Highways ranging from a rural, light traffic, Farm to Market highway to a highly traveled Interstate Loop around one of this states major cities. These roadways vary from 250 vehicles per day to greater than 60,000 vehicles per day. These sections were constructed according to Texas Highway Department Standard Specification 340 (Hot Mix Asphaltic Concrete) and 320 (One Course Surface Treatments).

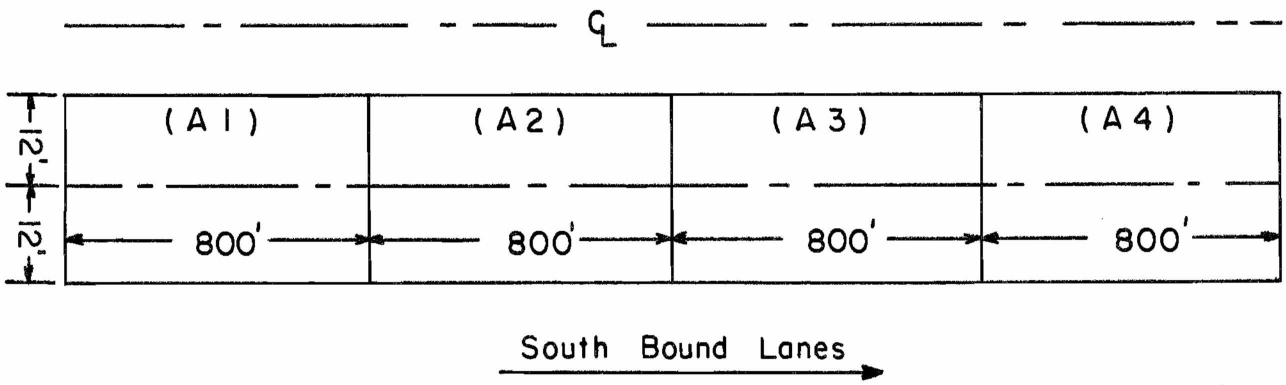
Test Section A (Figure 1)

This surface treatment section was constructed on a rural Interstate Highway in August 1965, and is composed of 4 segments, each 800 feet in length, with each segment having a different coarse aggregate type. The aggregate types used were (1) a dolomitic limestone, (2) a synthetic lightweight, (3) a crushed limestone and (4) a crushed trap rock. The traffic on this section has increased from an average daily traffic (ADT) of approximately 10,000 at time of placement to greater than 16,000 average daily traffic in 1970. Segment A3 or the lightweight segment was placed with an aggregate cover of 1 cubic yard aggregate: 99 square yards of surface area and an asphalt rate of 0.241 gallons per square yard. The lightweight aggregate used was Grade 4 under Texas Highway Department Specification Item 1269. Segment A1, dolomitic limestone; Segment A2 crushed limestone; and Segment A4, trap rock were placed with an average aggregate cover from 1 cubic yard aggregate: 120 square yards of surface area, 1 cubic yard aggregate: 140 square yards of surface area. The asphalt rate of application was approximately 0.350 gallons per square yard.

TEST SECTION A

Purpose of Placement: Study Friction and Polishing Characteristics of Aggregate Used in Seal Course Surface Treatments.

I.H. 35 Near Buda, Texas



Section Designation	Material	Agg. Rate CY/SY	Asphalt Rate Gal/SY	Agg. Grade
A1	Dolomitic Limestone	1:120 to 1:140	0.350	4
A2	Calcareous Limestone	1:120 to 1:140	0.350	4
A3	Lightweight	1:99	0.241	4
A4	Trap Rock	1:120 to 1:140	0.350	4

Placed: August 1965

Traffic (ADT): 10,000 - 1965
16,000 - 1970

Comments: Test Section is still in service as of March 1971. Surface looked very good after placement. Slight flushing noted in Segments A3 and A4 (darker colored aggregate) after 9,500,000 traffic applications.

Figure 1

Test Section B (Figure 2)

This section, which was located on an Interstate Loop around a major Texas city, was composed of 7 different Hot Mix Asphaltic Concrete pavement surfaces with the coarse aggregates in each being different from its adjoining segment. Each of these segments was 800 feet in length.

The following materials and percentages were used:

	Material	% C.A.	% F.A. (Limestone)	Type of Mix
B1	Aluminum Slag	70%	30	E
B2	Trap Rock	35%	65	D
B3	Dolomitic Limestone	35%	65	D
B4	Synthetic Lightweight	35%	65	D
B5	Flint	35%	65	C
B6	Crushed Limestone with a grade 4 precoated stone broadcast over the surface - Called the "English Method".	50-70%	50-30	D
B7	Crushed Limestone	50-70%	50-30	D

The type of mixes mentioned above conform to Texas Highway Department Standard Specification Item 340.

The section called "English Method" was constructed in the following manner:

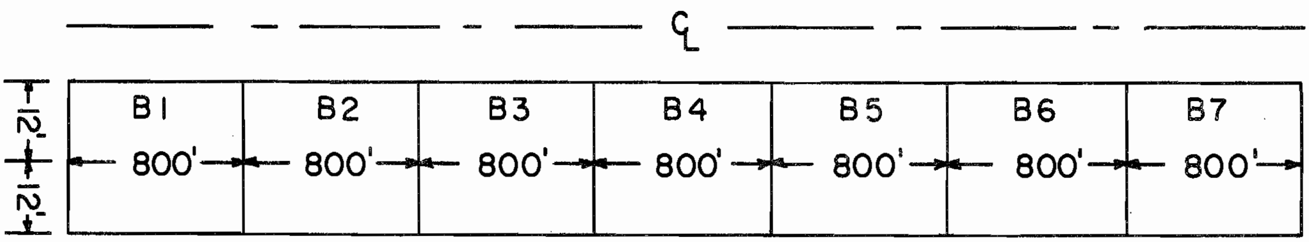
1. The crushed limestone HMAC was placed with the laydown machine.

2. The application of the precoated stone was attempted as follows:

(a) In the first attempt, the rollers rolled the mix immediately after laydown, then the stone was broadcast and rolled a second time. The stone appeared very loose and did not penetrate the mix. This procedure was used for approximately 50 feet at the beginning.

TEST SECTION B

I.H. 410 San Antonio, Texas



Placed: August 1966

Traffic (ADT): 15,600 - 1966
29,200 - 1970

Comments: Test Section was overlaid in August 1970.

Section Designation	Aggregate Type	% Asphalt	Hot Mix Type*
B1	Aluminum Slag	6.7	E
B2	Trap Rock	5.2	D
B3	Dolomitic Limestone	5.2	D
B4	Synthetic Lightweight	6.3	D
B5	Flint	5.0	C
B6	Crushed Limestone	5.0	D
B7	Crushed Limestone	5.0	D

*Standard Aggregate Gradations for the mix types mentioned above are found in the Appendix.

Figure 2

(b) In the final attempt, the mix was placed, the stone was scattered and then the surface was rolled. Air temperature was cool during placement (50 -60 F) and the mix temperature varied from 150 F to 160 F when rolled. The precoated stone was not heated before being scattered and was believed to be near embient temperature. By the next day all precoated stone was gone, leaving holes where it was located.

Test Section C (Figure 3)

This Hot Mix Asphaltic Concrete section was placed in the summer of 1968 on Interstate 35 through the capitol city of this state in an effort to increase the skid resistance of the Austin Expressway. The surface matrix of this roadway is a combination of 54% (by weight) lightweight synthetic aggregate, 23% slag (aluminum), 8% limestone screenings, 8% field sand, and 7% asphalt. Average daily traffic has increased from approximately 49,000 vehicles per day at the time of placement to greater than 60,000 vehicles per day at the present time.

This test section has produced remarkable results. Wet weather accidents have decreased by a large percentage, and there has been (almost) a steady increase in coefficient of friction since the time of placement. Friction values for this section were obtained at 40 m.p.h. instead of at 50 m.p.h. as were all other test sections. This was done in order that this safety overlay could be better compared with similar roadways throughout the country.

Test Section D (Figure 4)

In the summer of 1966 a section was placed on an Interstate Highway bridge deck in an urban area. This section was designed by Texas Highway Department District personnel in an attempt to find a thin asphaltic concrete suitable for bridge overlays. Three different and very small coarse aggregate

TEST SECTION C

Purpose of Placement: Overlay was placed in all lanes in an attempt to reduce wet pavement accidents on a high traffic expressway.

Limits: From: U.S. 183
To: Colorado River

Placed: Summer 1968

Traffic (ADT): 49,000 - 1968
61,000 - 1970

LABORATORY INFORMATION[2]

Screen Size	Design (Plant)	Average Extraction Gradation	Average Combined Bin Analysis
5/8 - 1/2	0.5	0.3	0.6
1/2 - 3/8	8.7	7.4	10.1
3/8 - 4	34.2	36.7	34.1
4 - 10	14.3	12.0	15.1
+ 10	57.7	56.4	59.9
10 - 40	19.3	20.5	20.8
40 - 80	7.5	7.5	6.4
80 - 200	5.3	5.3	3.7
- 200	3.2	3.5	2.2
% Asphalt	7.0	6.8	7.0
	100.0	100.0	100.0

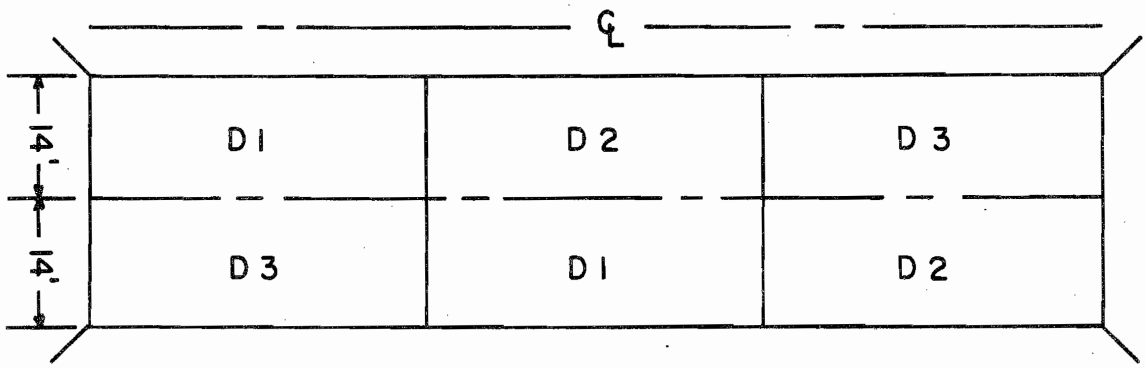
Average Percent Density (Laboratory)	94.3
Average Percent Stability	51
Average Sand Equivalent Value	86

Asphalt used for this Project was American Petrofina - Mt. Pleasant, Texas (AC-10)

Figure 3

TEST SECTION D

I.H. 20 Fort Worth, Texas, Camp Bowie Blvd. Overpass



Section Designation	Material	Type
D1	Trap Rock	E
D2	Blast Furnace Slag	E
D3	Synthetic Lightweight	E

Placed: Summer 1966

Traffic (ADT): 30,000 - 1966
50,000 - 1970

Comments: Purpose was to test thin asphaltic concrete which would be suitable for bridge overlays. Completed mix was very impervious.

Figure 4

types were used in separate segments. Segment D1 was composed of 40% trap rock, 40% limestone screenings, and 20% field sand, and 7.0% asphalt. Segment D2 was composed of 40% blast furnace slag, 40% limestone screenings, and 20% field sand, and 7.0% asphalt. Segment D3 was composed of 40% synthetic (lightweight), 40% limestone screenings, and 20% field sand, and 10.0% asphalt. Latex rubber was added to each mix in the pug mill at the rate of 3% by weight based on the amount of asphalt.

Test Section E (Figure 5)

This section is composed of seven segments of HMAC with various aggregate types and combinations for each segment. Segment E1 consists of 60% crushed gravel screenings, 20% shell, 20% field sand, and 6.5% asphalt. Segment E2 consists of 68% crushed river gravel screenings, 12% limestone screenings, 20% field sand, and 5.7% asphalt. Segment E3 consists of 45% aluminum furnace slag, 20% crushed gravel screenings, 20% limestone screenings, 15% field sand, and 6.3% asphalt. Segment E4 consists of 50% crushed river gravel, 12% crushed gravel screenings, 18% shell, 20% field sand, and 5.7% asphalt. The mix in Segment E5 consists of the following proportions: 55% crushed gravel, 25% crushed gravel screenings, 20% field sand, and 5.3% asphalt. The surface of Segment E6 consists of 44% synthetic aggregate (lightweight), 26% shell, 30% field sand, and 7.5% asphalt. The Segment E7 mix consists of the following: 46% synthetic aggregate (lightweight), 24% crushed gravel screenings, 30% field sand, and 6.7% asphalt.

At the time of construction in 1967 the average daily traffic was 8,565 vehicles per day, and at the present the ADT is greater than 10,000 vehicles per day.

The following comparisons of the segments of this test section are made to show the effects of different aggregate types and size on the coefficient of friction.

Test Segment	Material Types
E1	Crushed Gravel Screenings Shell
E2	Crushed Gravel Screenings Limestone Screening
E3	Aluminum Slag Limestone Screenings Crushed Gravel Screenings
E4	Crushed Gravel Crushed Gravel Screening Shell
E5	Crushed Gravel Crushed Gravel Screenings
E6	Synthetic (Lightweight) Shell
E7	Synthetic (Lightweight) Crushed Gravel Screenings

For Type E Mixes

Segment	Friction at 4 Million Vehicle Applications
E1	28
E2	36
E3	30

For Type H Mixes

Segment	Friction at 4 Million Vehicle Applications
E4	31
E5	34
E6	42
E7	48

I. A comparison of the Type E Mixes to the Type H shows that the average of the coefficients for four Type H Mixes is 8 skid numbers higher than the average of the three Type E Mixes.

II. A comparison of the addition of Aluminum Slag in a Type E Mix shows:

Segment	Material Types	Skid Number	
E2	Crushed Gravel Screenings Limestone Screenings	36	6
E3	Aluminum Slag Limestone Screenings Crushed Gravel Screenings	30	

III. A comparison of the addition of crushed gravel as the coarse aggregate in the mix shows:

Segment	Material Types	Skid Number	
E1	Crushed Gravel Screenings Shell	28	3
E4	Crushed Gravel Crushed Gravel Screenings Shell	31	

IV. A comparison of the addition of Shell in a Type H Mix shows:

Segment	Material Types	Skid Number	
E5	Crushed Gravel Crushed Gravel Screenings	34	3
E4	Crushed Gravel Crushed Gravel Screenings Shell	31	

V. A comparison of Shell to Limestone Screenings in a Type E Mix shows:

Segment	Material Types	Skid Number	
E1	Crushed Gravel Screenings Shell	28	8
E2	Crushed Gravel Screenings Limestone Screenings	36	

VI. A comparison of Shell to Crushed Gravel Screenings in a Type H Mix shows:

Segment	Material Types	Skid Number	
E6	Lightweight Shell	42	6
E7	Lightweight Crushed Gravel Screenings	48	

VII. A comparison of Crushed Gravel Screenings (Type E Mix) to Lightweight (Type H Mix) shows:

Segment	Material Types	Skid Number	
E1	Crushed Gravel Screenings Shell	28	14
E6	Lightweight Shell	42	

VIII. A comparison of Crushed Gravel (Type H Mix) to Lightweight (Type H Mix) shows:

Segment	Material Types	Skid Number	
E5	Crushed Gravel Crushed Gravel Screenings	34	14
E7	Lightweight Crushed Gravel Screenings	48	

From the above comparisons the following conclusions can be drawn from Test Section E:

1. The addition of coarse aggregate in the mix improved the friction as determined from the following:

   III. - 50% of the crushed gravel screenings was replaced with crushed gravel and the result was a skid number improvement of 3.

   VII. - 44% of the curshed gravel screenings was replaced with lightweight resulting in a skid number improvement of 14.

2. The type of coarse aggregate has an effect on friction as determined from the following:

   VII. - The lightweight with crushed gravel screenings mix was found to have skid numbers higher than the crushed gravel with crushed gravel screenings mix. The skid number difference was 14.

3. The use of different fine aggregates produced small variations in skid numbers as determined by the following:

   IV. - The substitution of crushed gravel screenings with 18% shell lowered the skid numbers by a value of 3.

   V. - The use of limestone screenings produced higher SN values as compared to oyster shell. The difference in skid numbers was 8.

   VI. - The use of crushed gravel screenings produced higher SN values as compared to oyster shell. The difference in SN Values was 6.

By comparing item V to item VI it would appear that limestone screenings would produce higher friction as compared to crushed gravel screenings. The fine aggregate could be ranked for friction in this project as follows:

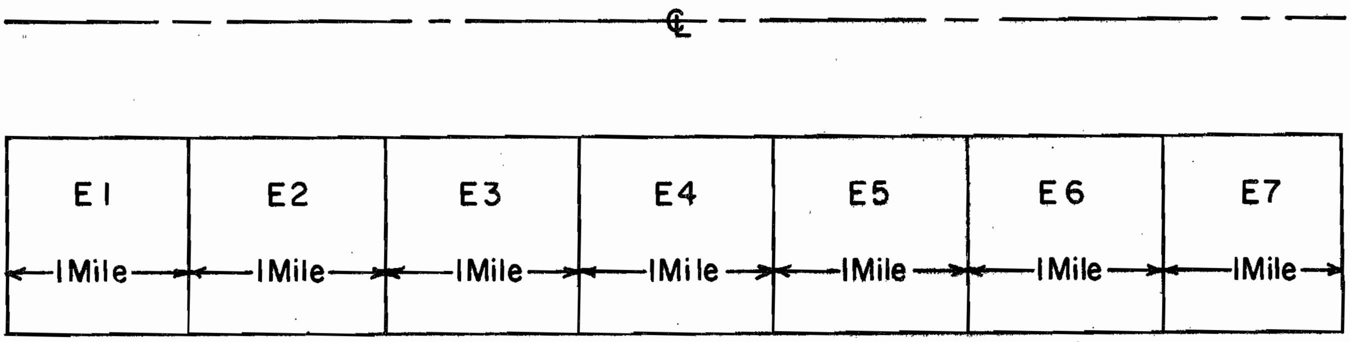
1. Limestone Screenings
2. Crushed Gravel Screenings
3. Shell

4. In this test section the coarse aggregate influenced the skid numbers more than did the fine aggregate. This conclusion was obtained by comparing conclusions 1 and 2 with conclusion 3. However the type of coarse aggregate used must also be considered in developing this conclusion.

TEST SECTION E

U.S. 59 Fort Bend County

Limits: Rosenberg to Wharton



Section Designation	Material	Type
E1	Crushed Gravel Screenings, Shell	E
E2	Crushed Gravel Screenings, Limestone Screenings	E
E3	Aluminum Slag, Crushed Gravel Screenings, Limestone Screenings	E
E4	Crushed River Gravel, Crushed River Gravel Screenings, Field Sand & Shell	E
E5	Crushed Gravel, Crushed Gravel Screenings & Field Sand	H
E6	Lightweight, Shell & Field Sand	H
E7	Lightweight, Crushed Gravel Screenings & Field Sand	H

Placed: Summer 1967

Traffic (ADT): 8,565 - 1967
10,000 - 1970

Figure 5

Test Section F (Figure 6)

This test section was placed on a state designated highway in November 1966. It was placed in 3 segments with each segment having a different coarse aggregate type. Segment F1 consists of an HMAC surface of 80% (iron) blast furnace slag, and 20% field sand, and 6.7% asphalt. Segment F2 is an HMAC surface consisting of 57% (iron) blast furnace slag, 24% shell, and 19% field sand, and 6.1% asphalt. Segment F3 is an HMAC surface consisting of 72% aluminum slag, 19% limestone screenings, and 9% field sand, and 6.3% asphalt.

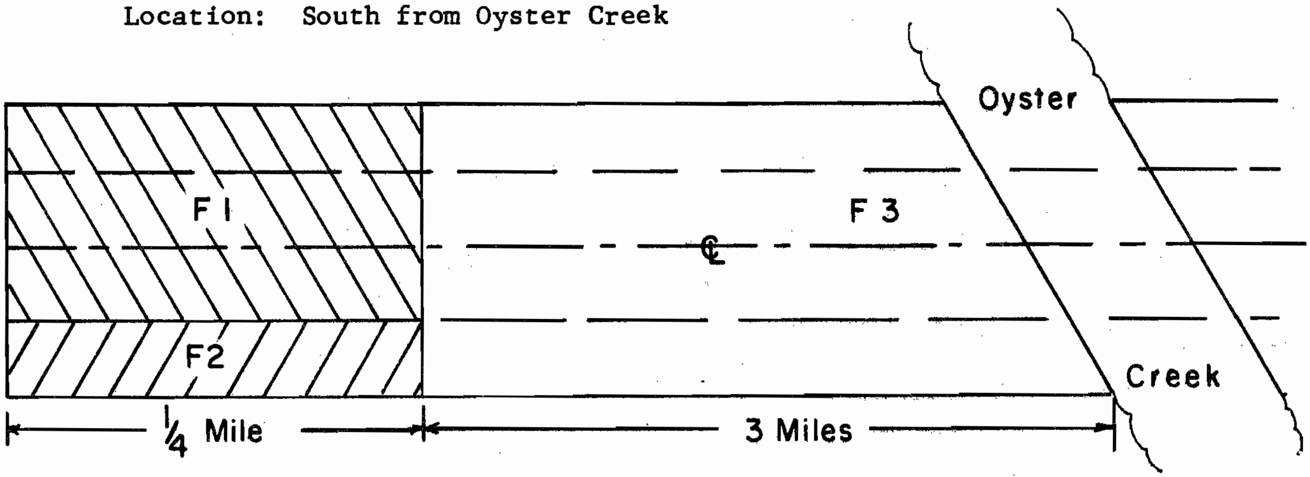
Test Section G (Figure 7)

This section is composed of twelve HMAC segments using different commercially produced synthetic (lightweight) aggregates. Each commercial aggregate was used in two segments with different asphalt contents. All segments were composed of approximately 50% lightweight aggregate and 50% aluminum slag. This test section was placed in September 1968, in both lanes of a two lane Farm to Market highway. Segments G1 and G2 are in opposite lanes and are composed of 50.8% lightweight and 49.2% aluminum slag. These segments were placed with 7.5% (by weight) AC-20 asphalt. Segments G3 and G4 were placed in opposite lanes using 44% lightweight aggregate, and 56% aluminum slag. These segments were placed with a 7.5% asphalt content. Segments G5 and G6 were placed using the same proportioning of aggregates with an 8.5% asphalt content. Segments G7 and G8 were placed with an asphalt content of 8.5%. The coarse aggregate was a commercially produced lightweight of unknown origin. The design gradation of the materials was the same as in segments G3 through G6. Segments G9 and G10 are composed of 49.5% lightweight and 50.5% aluminum slag, placed with a 7.0% asphalt content. Segments G11 and

TEST SECTION F

S.H. 288 Brazoria County

Location: South from Oyster Creek



Section Designation	Material	Type
F1	Iron Ore Slag W/Field Sand	H
F2	Iron Ore Slag, Shell & Field Sand	H
F3	Aluminum Slag, Limestone Screenings, & Sand	E

Placed: November 1966

Traffic (ADT): 3,500 - 1966
5,200 - 1970

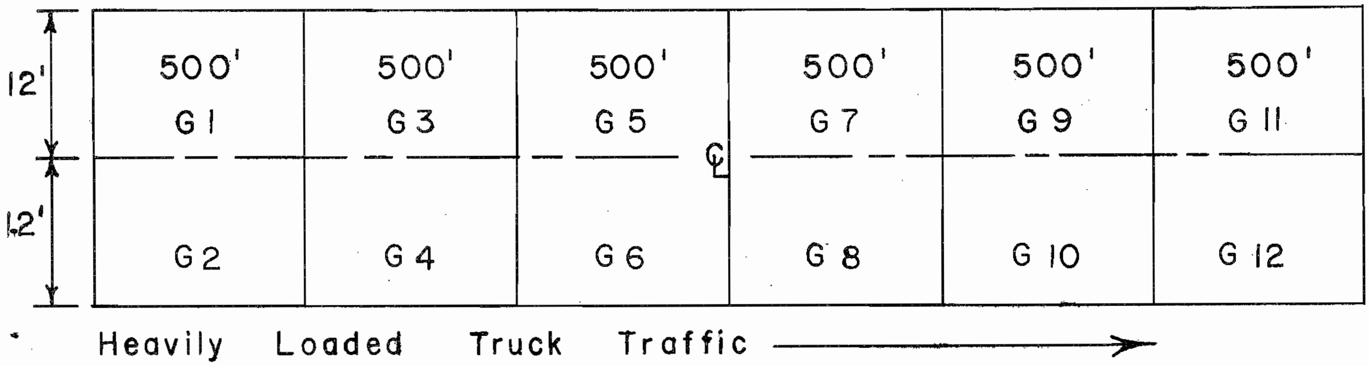
Comments: All three segments are holding up very well under traffic.

Figure 6

TEST SECTION G

F.M. 1687 Brazos County

Location: Near Bryan, Texas



Section Designation	Material	% Asphalt	Type
G1	Lightweight & Aluminum Slag	7.5%	D
G2	" " " "	7.5%	"
G3	" " " "	7.5%	"
G4	" " " "	7.5%	"
G5	" " " "	8.5%	"
G6	" " " "	8.5%	"
G7	" " " "	8.5%	"
G8	" " " "	8.5%	"
G9	" " " "	7.0%	"
G10	" " " "	7.0%	"
G11	" " " "	8.0%	"
G12	" " " "	8.0%	"

Placed: September 1968

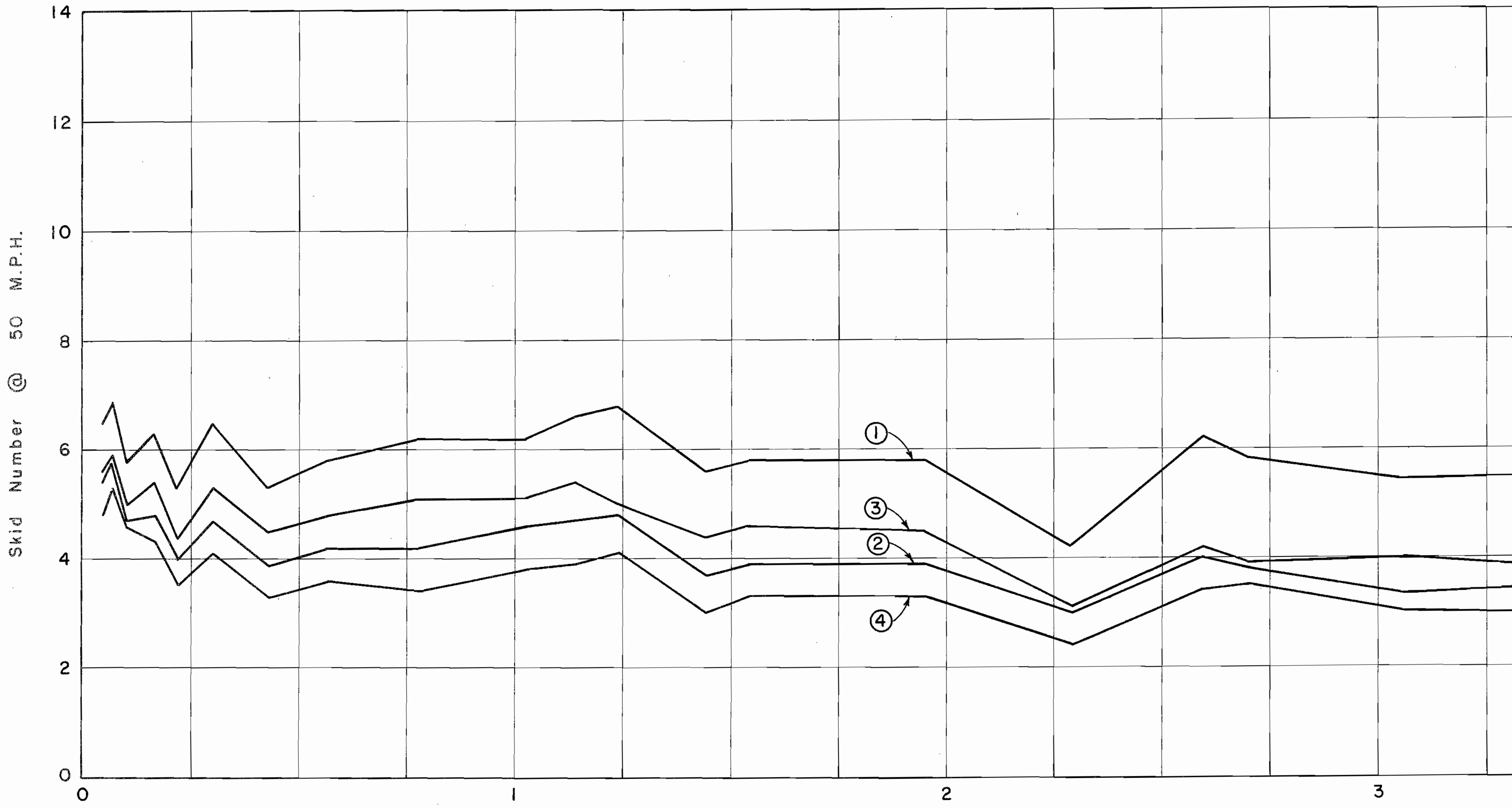
Traffic (ADT): 150 - 1968
400 - 1970

Comments: Aggregate from four different producers was used in this section. Variations in asphalt content and lightweight sources were used to check structural life and skid resistance. This section is located near a large commercial aggregate source and receives a very large percentage of heavily loaded truck traffic in one direction and empty truck traffic in the other.

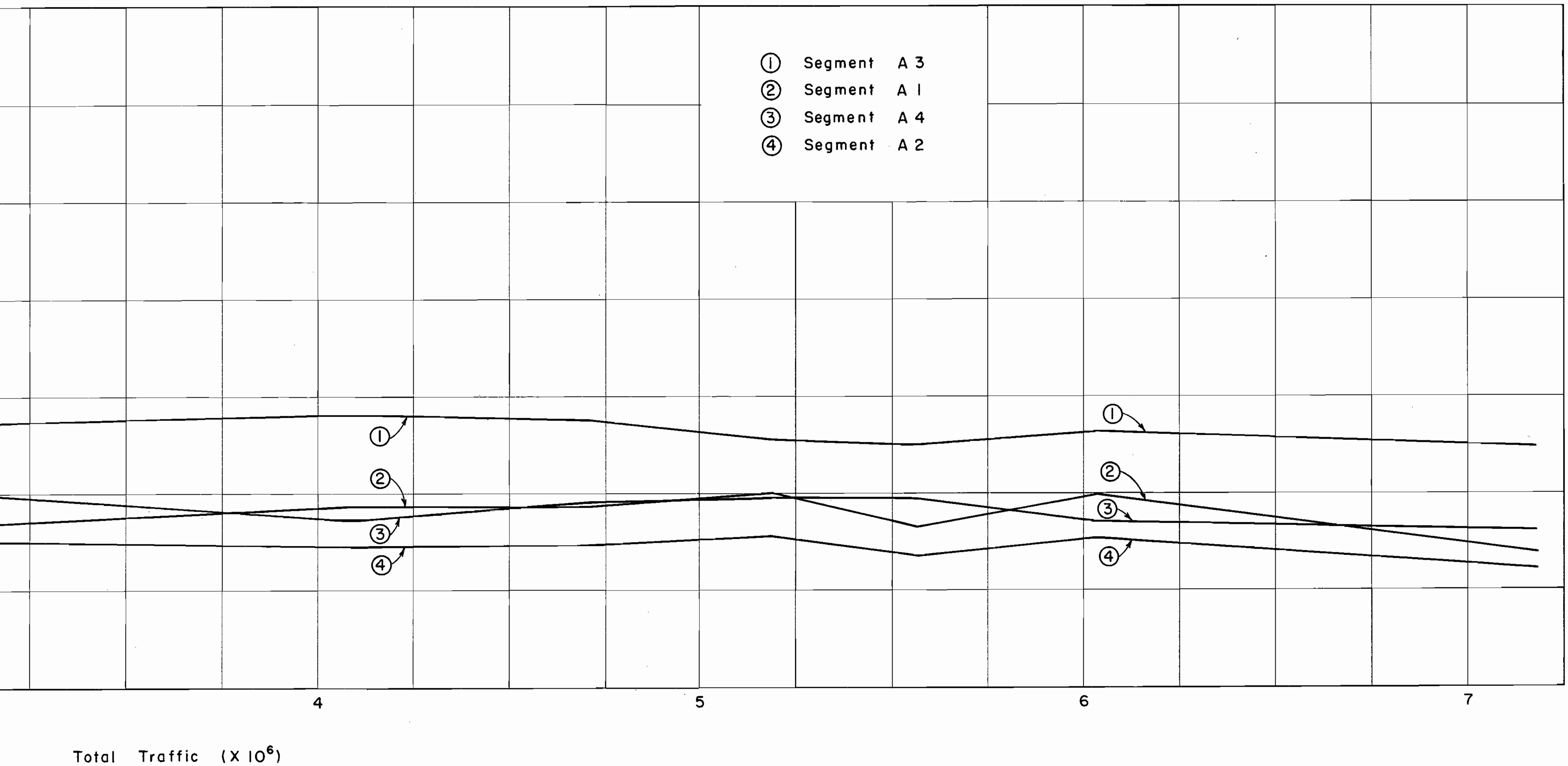
Figure 7

G12 are composed of the same coarse aggregates used in the same proportions as the mixes in segments G9 and G10, but the asphalt content used was 8.0%.

The frictional properties of the sections previously mentioned are discussed in the next chapter.



14
12
10
8
6
4
2
0
Skid Number @ 50 M.P.H.
0
1
2
3
1
3
2
4



TEST SECTION A

Figure 8

III. DISCUSSION AND RESULTS

The field friction performance studies of these test sections show that a good surface with a resistance to polishing under heavy traffic can be placed. The change in the measured friction values for these aggregates follows the same trend in both the field and the laboratory. (The British Accelerated Polish Machine, which is used in the laboratory to effect polishing, will be discussed in the next interim report of this study.) This trend is a decrease in the coefficient of friction to a level, (That is, on a friction vs cummulative traffic plot the best fit curve is hyperbolic and the curve becomes a symptotic as cummulative traffic increases) with no significant change in friction after that - even with repeated traffic applications. The Austin Expressway is an exception to the above trend as it has not begun to decrease in friction but is still rising. The results of this test section, along with all others, are shown in Table I.

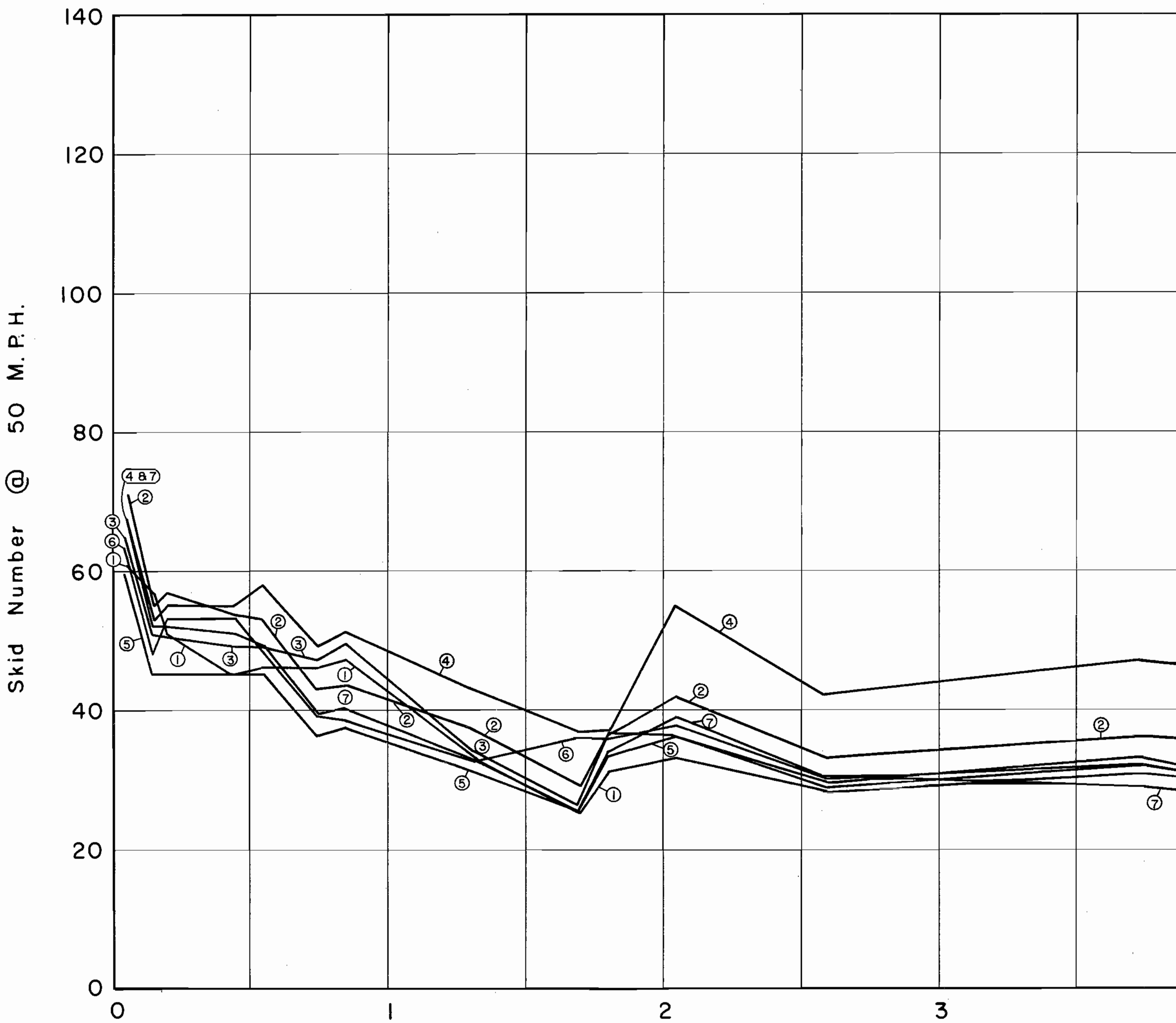
As indicated by Table I, almost all aggregates polish (change in frictional characteristics) when exposed to continued traffic applications. A graphical representation of the measured coefficient of friction is shown in Figures 8 through 13. The graphs show measured coefficients of friction plotted against total accumulated traffic at the time of measurement. Total accumulated traffic is obtained by taking the average daily traffic (ADT), dividing by the number of lanes in the roadway and multiplying by the number of days since the test section was placed. This is not an exact method for determining total accumulated traffic applications. However, it is believed that this method is sufficient to reveal the wear (polish) characteristics of roadway surface materials.

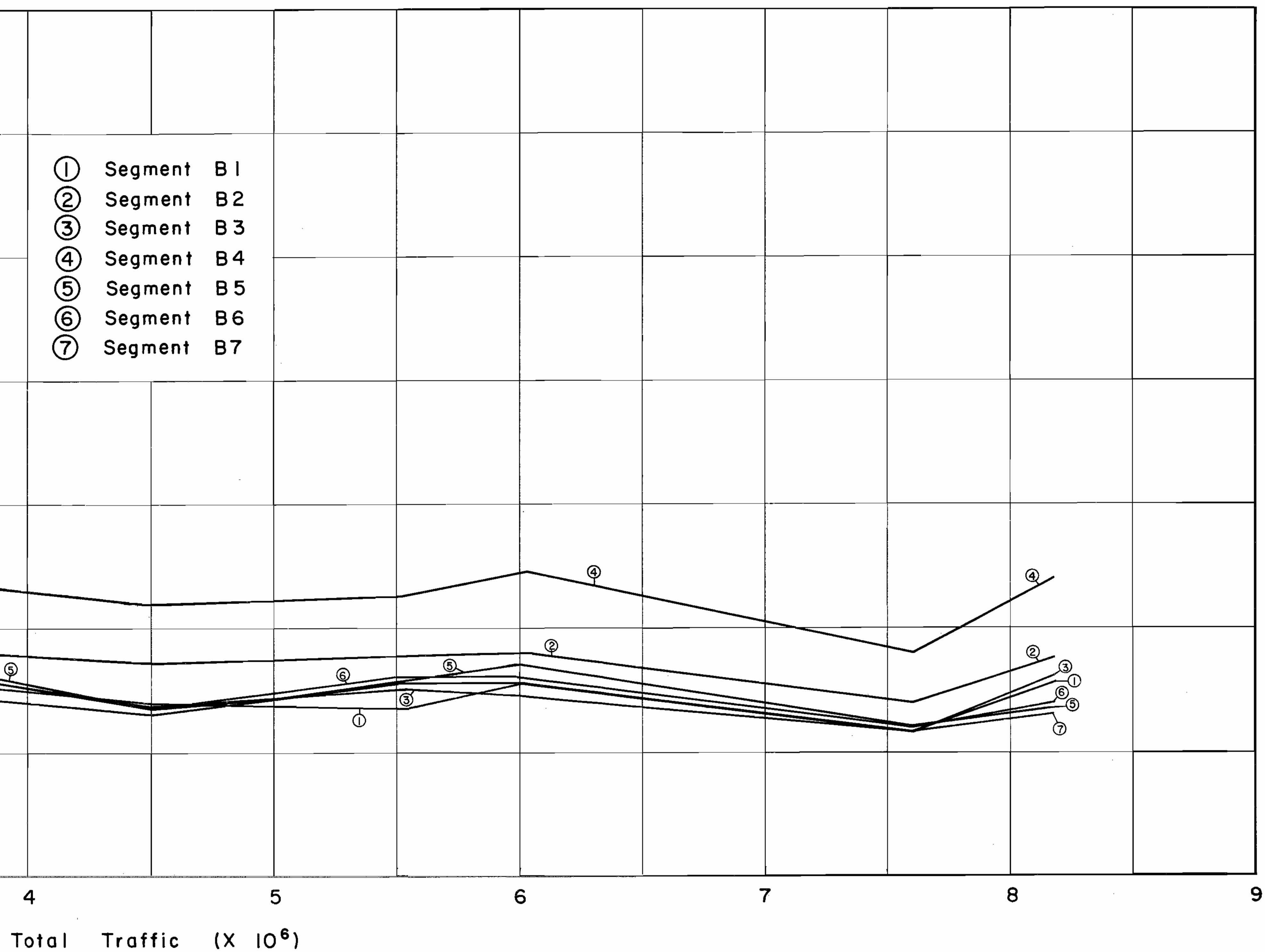
TABLE 1

Segment	Initial Friction Value	Total Traffic	High Friction Value	Total Traffic	Low Friction Value	Total Traffic	Material Type
A1	54	49,000	58	70,000	28	2,287,000	Dolomitic Limestone
A2	48	49,000	53	70,000	24	2,287,000	Crushed Limestone
A3	65	49,000	69	70,000	42	2,287,000	Synthetic Lightweight
A4	56	49,000	59	70,000	31	2,287,000	Trap Rock
B1	61	54,600	61	54,600	26	7,623,000	Slag
B2	71	54,600	71	54,600	28	7,623,000	Trap Rock
B3	65	54,600	65	54,600	23	7,623,000	Dolomitic Limestone
B4	67	54,600	67	54,600	36	7,623,000	Synthetic Lightweight
B5	59	54,600	59	54,600	23	7,623,000	Flint
B6	64	54,600	64	54,600	24	7,623,000	English Method
B7	68	54,600	68	54,600	24	7,623,000	Crushed Limestone
C	47	455,000	56	9,500,000	45	2,185,000	Lightweight & Slag
D1	48	17,000	48	17,000	25	2,600,000	Trap Rock
D2	52	17,000	52	17,000	28	2,600,000	Slag
D3	64	17,000	64	17,000	27	2,600,000	Lightweight
E1	42	22,000	45	1,050,000	29	4,000,000	Crushed Gravel Screenings
E2	43	22,000	52	1,050,000	37	4,000,000	Crushed Gravel Screenings
E3	43	22,000	47	1,050,000	32	4,000,000	Aluminum Slag
E4	43	22,000	49	1,050,000	33	4,000,000	Crushed Gravel
E5	47	22,000	51	1,050,000	35	4,000,000	Crushed Gravel
E6	45	22,000	61	1,050,000	42	4,000,000	Lightweight
E7	54	22,000	64	1,050,000	47	4,000,000	Lightweight
F1	51	225,000	52	1,250,000	35	3,700,000	Aluminum Slag
F2	45	225,000	48	1,250,000	30	3,700,000	Slag & Shell
F3	46	225,000	46	225,000	27	3,250,000	Aluminum Slag

TABLE 1 (Continued)

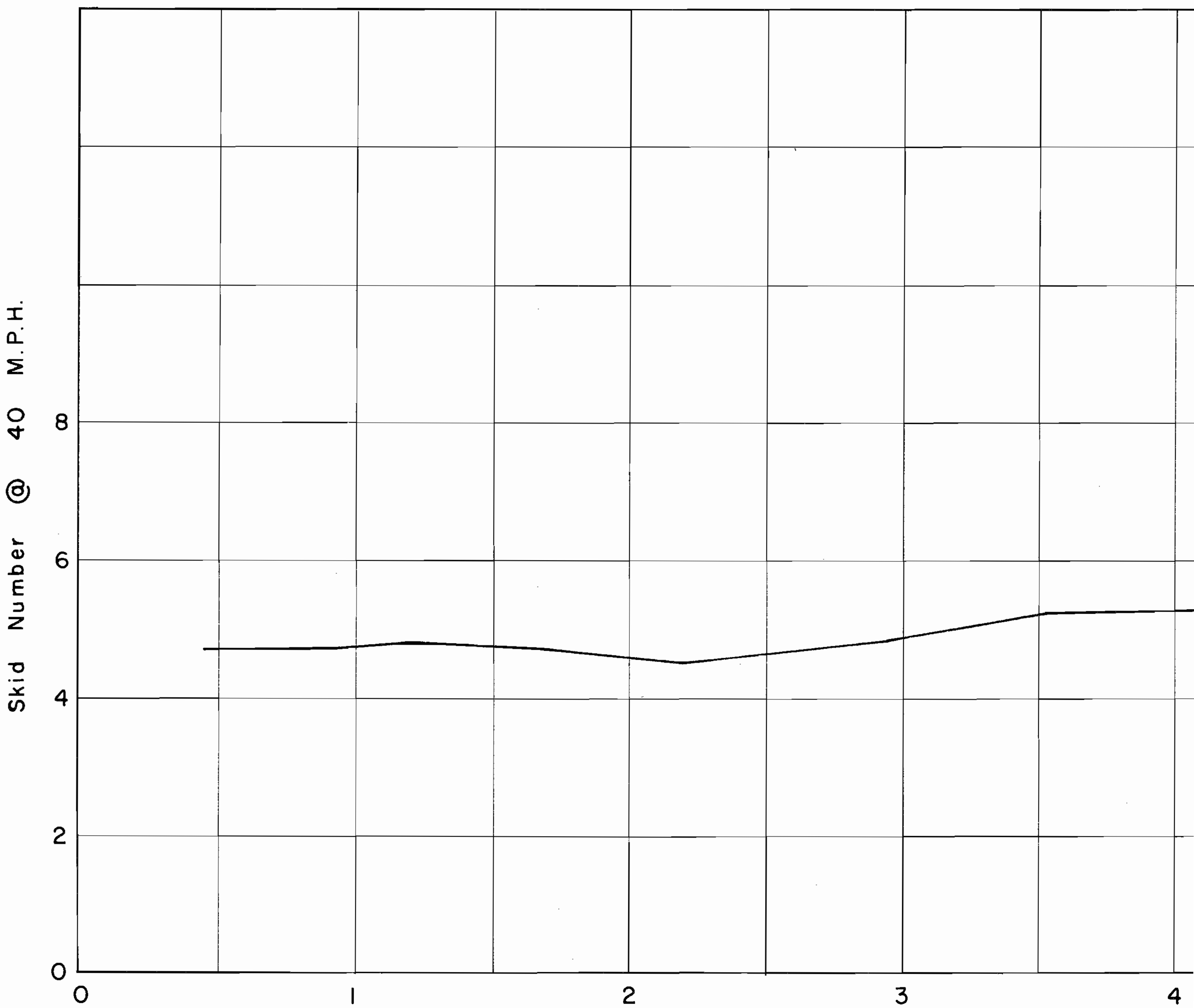
Segment	Initial Friction Value	Total Traffic	High Friction Value	Total Traffic	Low Friction Value	Total Traffic	Material Type
G1 G2	52	3,500	62	17,500	49	15,700	Lightweight A & Slag @ 7.5% Asphalt
G3 G4	55	3,500	67	17,500	53	15,700	Lightweight B & Slag @ 7.5% Asphalt
G5 G6	56	3,500	62	17,500	52	15,700	Lightweight B & Slag @ 8.5% Asphalt
G7 G8	54	3,500	64	17,500	54	3,500	Lightweight C & Slag @ 8.5% Asphalt
G9 G10	59	3,500	63	17,500	57	15,700	Lightweight D & Slag @ 7.0% Asphalt
G11 G12	57	3,500	58	12,000	56	15,700	Lightweight D & Slag @ 8.0% Asphalt

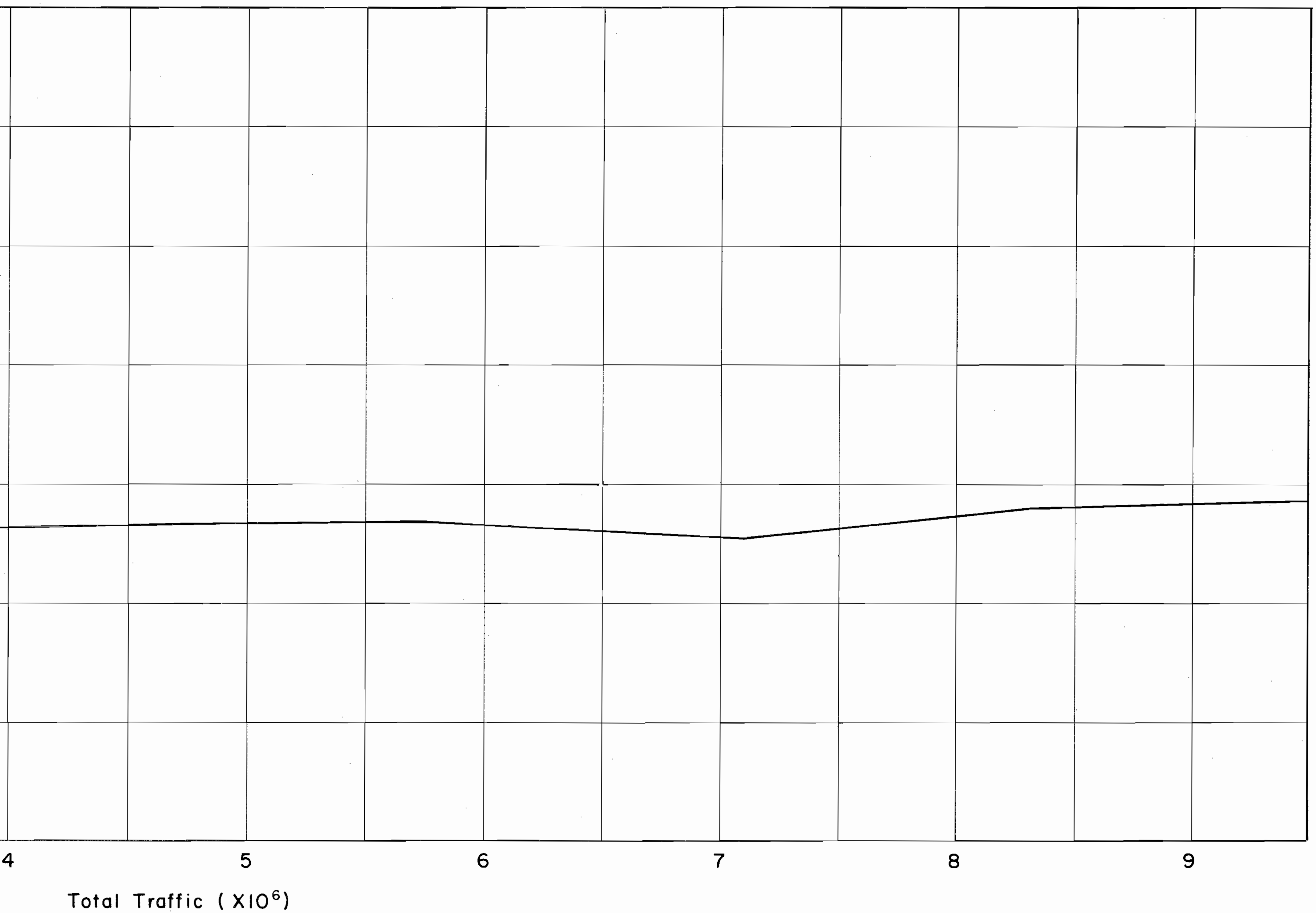

Skid Number @ 50 M.P.H.
140
120
100
80
60
40
20
0
0
1
2
3
4 & 7
1
2
3
4
5
6
7



TEST SECTION B

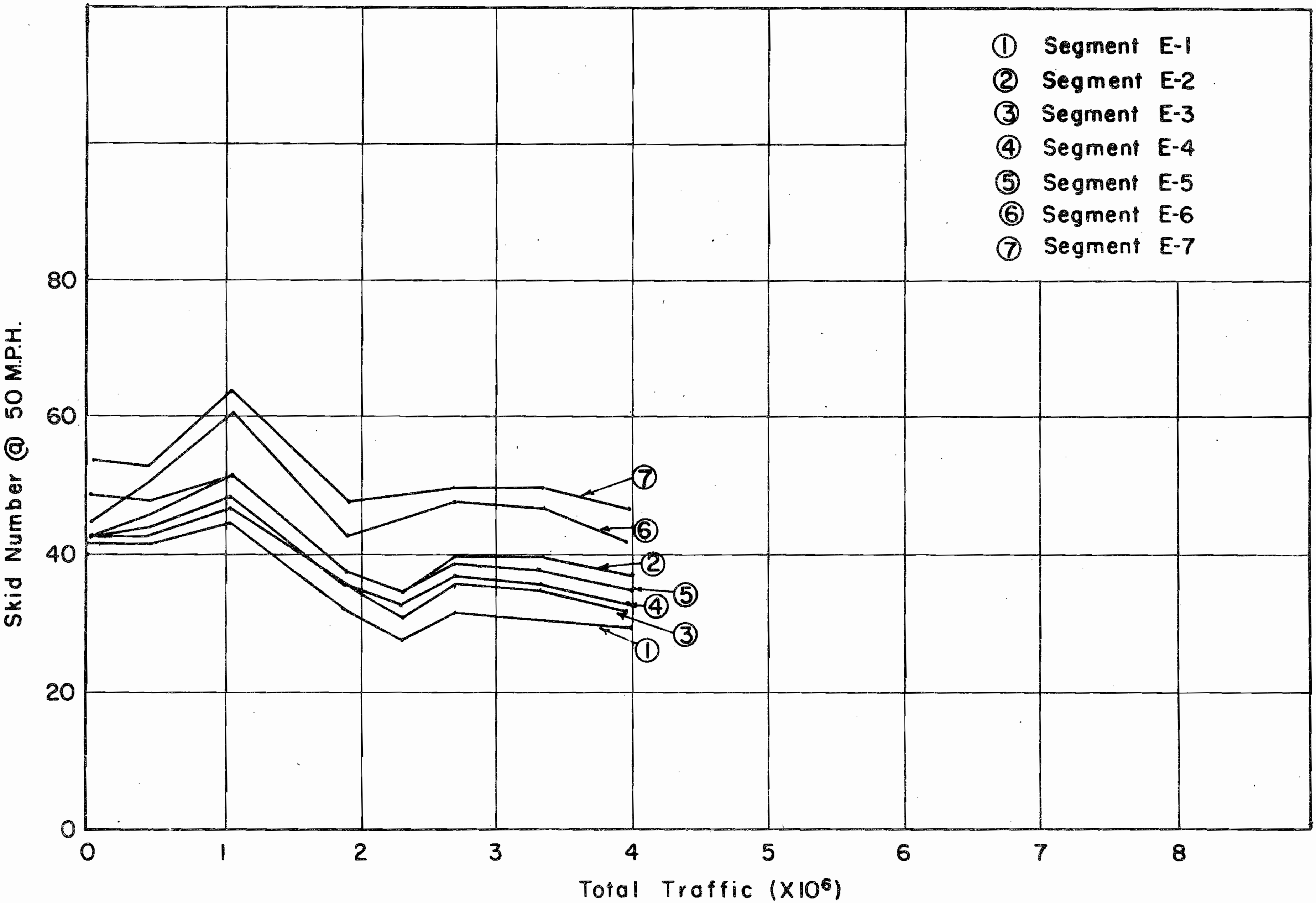
Figure 9


Skid Number @ 40 M.P.H.
0
2
4
6
8
0
1
2
3
4



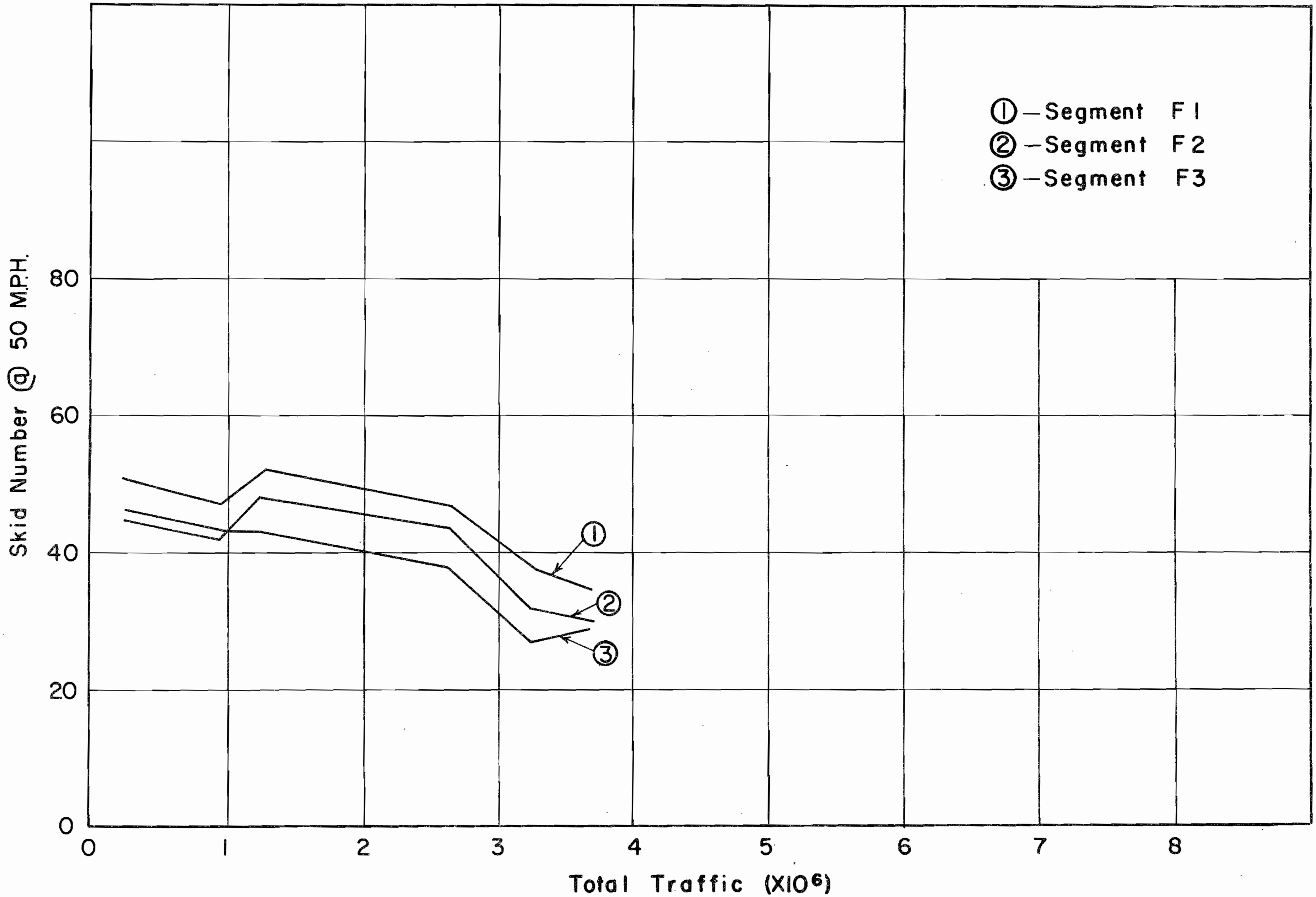
TEST SECTION C

Figure 10



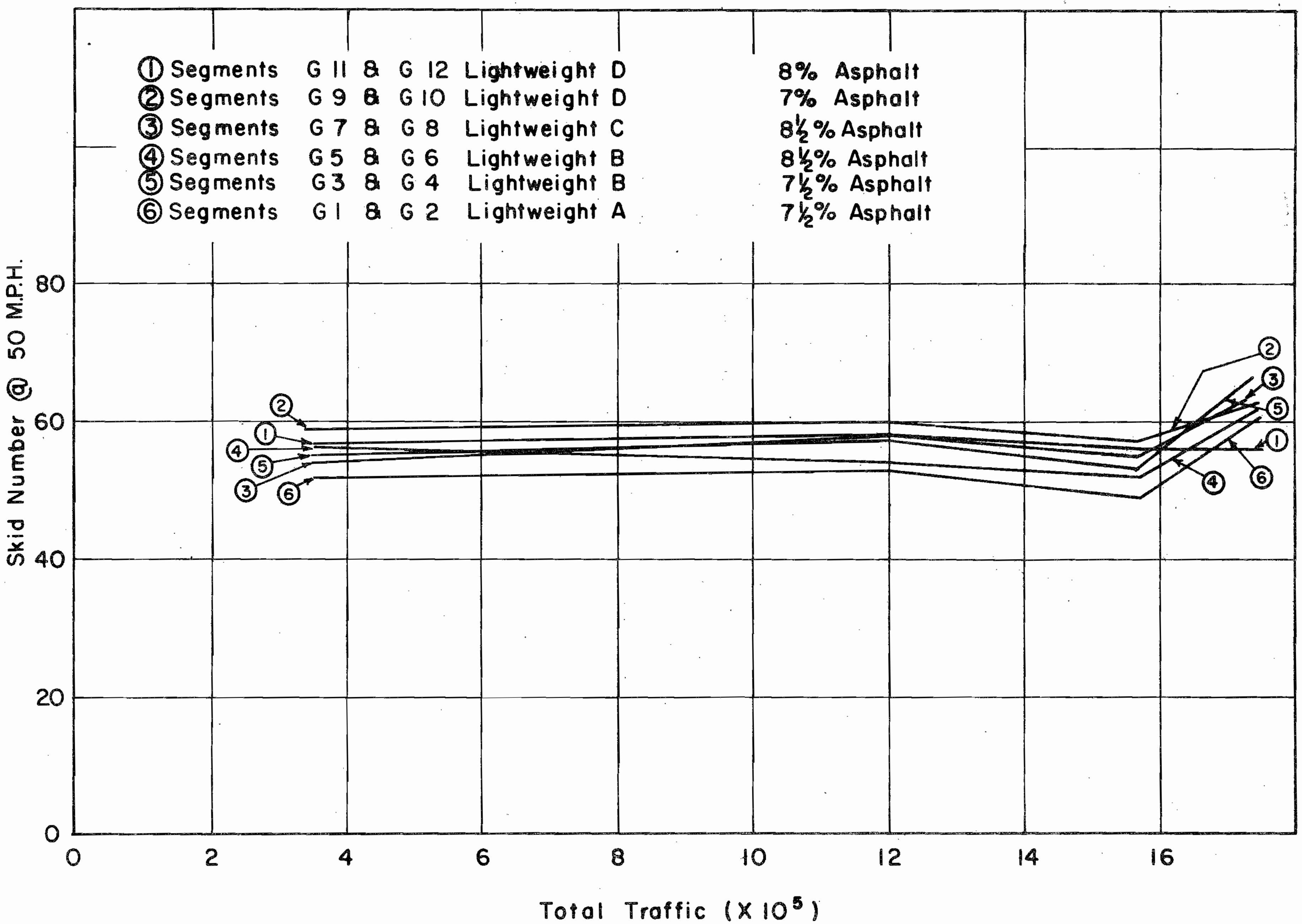
TEST SECTION E

Figure 11



TEST SECTION F

Figure 12



TEST SECTION G

Figure 13

IV. CONCLUSIONS

From this phase of the study the following conclusions can be drawn:

1. Synthetic aggregates, especially lightweights, exhibit a large resistance to polishing. It is believed these aggregates maintain their skid resistance characteristics because the vehicle tire opens new holes or "blibs", thereby increasing the micro-texture and altering the rate of polish.
2. Synthetic aggregates used in combination with polish susceptible aggregates tend to increase the coefficient of friction of the surface above that of a surface without the synthetic aggregate.
3. As revealed by the study of U.S. 59 (Test Section E), the fine aggregate type has a slight affect on the coefficient of friction during the latter stages of polish.
4. Friction must result from what the tire touches. As shown in this report, U.S. 59 shows more friction change in different coarse aggregates as compared to changes in intermediate or fine aggregates. Therefore, the coarse aggregate used is important, but the complete pavement matrix is most important. The importance of the coarse aggregate depends on the mix design used.
5. A comparison of the same aggregate types (Buda - Section A with San Antonio - Section B) shows the San Antonio section with very high initial friction.

   Section A is composed of a seal coarse in which aggregate from four sources were used. The same four sources were used within Section B. By studying each source separately it may be noted that, in each case, the material in the asphaltic concrete (Section B) revealed higher initial values as follows:

Source	Section A	Section B
Dolomitic Limestone	54	65
Crushed Limestone	48	68
Synthetic Lightweight	65	67
Trap Rock	56	71

From experience it is believed that a comparison of seal coarses and Hot Mix Asphaltic Concretes using the same aggregate would normally reveal the seal course with the higher initial friction values. The above comparison of Sections A and B reveal that Section B is an exception.

The initial values in Section B are unusually high for asphaltic concrete pavements which use similar materials for coarse aggregate. The exception to this statement is the lightweight material which is found with high initial values in most cases. An example of the above statment may be found by comparing the trap rock and aluminum slag in asphaltic concretes as follows:

For Trap Rock

Section B - 71

Section D - 48

For Aluminum Slag

Section B - 61

Section D - 52

Section E - 43

Section F - 51 - 46

It is believed that the large variance indicated above reveals construction differences rather than differences in mix design.

REFERENCES

1. Kummer, H. W. and Meyer, W. E., "Tentative Skid-Resistance Requirements For Main Rural Highways", Highway Research Board, NCHRP Report No. 37, 1967.

2. Gallatin, Gilbert L., "Report on Lightweight Aggregate Overlay Project On I.H. 35 Through Austin, Texas", Texas Highway Department, District 14, Austin, Texas, Summer 1968.

APPENDIX

Standard Texas Highway Department Hot Mix Gradations

STANDARD HOT MIX GRADATIONS

All gradations conform to Item 340 of the Texas Highway Department's Standard Specifications. The gradations are as follows.

Type "C" Hot Mix

Passing 7/8"	100
Passing 5/8"	95 to 100
5/8" - 3/8"	15 to 40
3/8" - No. 4	10 to 35
No. 4 - No. 10	10 to 30
Total + No. 10	50 to 70
No. 10 - No. 40	0 to 30
No. 40 - No. 80	4 to 25
No. 80 - No. 200	3 to 25
- No. 200	0 to 8

Type "D" Hot Mix

Passing 1/2"	100
Passing 3/8"	95 to 100
3/8" - No. 4	20 to 50
No. 4 - No. 10	10 to 30
Total + No. 10	50 to 70
No. 10 - No. 40	0 to 30
No. 40 - No. 80	4 to 25
No. 80 - No. 200	3 to 25
- No. 200	0 to 8

Type "E" Hot Mix

Passing No. 4	100
No. 4 - No. 10	0 to 5
No. 10 - No. 40	15 to 40
No. 40 - No. 80	20 to 45
No. 80 - No. 200	12 to 32
- No. 200	7 to 20

Type "H" Hot Mix

Passing 1/2"	100
Passing 3/8"	95 to 100
3/8" - No. 4	20 to 50
No. 4 - No. 10	10 to 30
Total + No. 10	60 to 75
No. 10 - No. 40	0 to 30
No. 40 - No. 80	4 to 25
No. 80 - No. 200	3 to 25
- No. 200	0 to 6