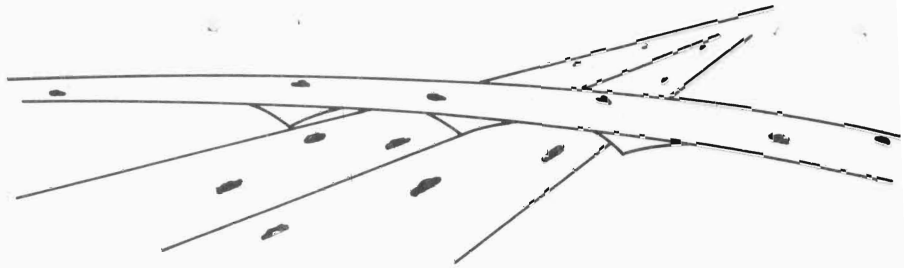


DEPARTMENTAL RESEARCH

Report Number: SS 11.4

MAINTENANCE OPERATIONS OF THE SKID TEST TRAILERS

[May 1968 – September 1968]

TEXAS HIGHWAY DEPARTMENT

MAINTENANCE OPERATIONS OF THE

SKID TEST TRAILERS

(May 1968 through September 1968)

by

Jon P. Underwood

Report Number SS 11.4

Conducted by

The Research Section of
The Highway Design Division
The Texas Highway Department

January, 1969

Table of Contents

List of Figures

Figure	Title	Page

List of Tables

ABSTRACT

Three skid test trailers have been built and are presently in operational use in Texas. This report covers the results for the first five months of operation indicating average results for the various types of surfaces, wear curves, the effect of binders and gradation of materials. The report will be of specific interest to the District, Maintenance, Design and Resident Engineers.

REPORT I

(May 1968-September 1968)

Maintenance Operations of the Skid Test Trailers

(First Five Months)
by Jon Underwood

Background

In May 1968, the D-4 shops completed the fabrication of three skid test trailers. It was decided that the Maintenance Operation Division would direct the operation of the trailers and the trailers would be stationed in District 5 (Lubbock), District 10 (Tyler) and District 15 (San Antonio). These districts are the districts in which the major supply warehouses are located.

Upon the completion of the fabrication, two training sessions were held. The first training section consisted of the orientation of the trailer operators. This orientation contained the calibration and operation of the trailer as well as the repair and maintenance of the trailers. The second session concerned the training of the observers. The Observers were previously selected by the districts upon request from the maintenance operations division. The Observer training consisted of a review of the coding methods and code sheet of the skid resistance computer program. During the training period the Observers rode with the driver in actual operating conditions, collected the raw skid resistance data, and prepared this information for submission to the Division of Automation for processing.

Therefore, the procedure of the skid resistance work is as follows:

1. The District desiring skid resistance work contacts the appropriate District in which a skid trailer is based.

2. The trailer and Operator are sent to the requesting District.

3. The Observer (having been previously orientated as to the desired test locations) and the Operator test the desired locations.

4. The District Observer prepares the skid resistance information for submission to the Division of Automation.

5. The Division of Automation processes the skid data and forwards a copy to the Maintenance Operations Division, the requesting District and the Design Division.

6. The Maintenance Operation Division will maintain a state-wide file as an assist in maintenance operations, particularly those between D-18 and the District.

7. The Design Division will maintain a state-wide file in assistance to plan preparation, particularly between D-8 and the District.

8. Efforts are being made to prepare a yearly report of the state-wide status of the pavement surfaces as related to skid resistance. This is the first such report.

General Information

The results later mentioned in this report may be biased because of the manner in which the surfaces to be tested were selected. The equipment was sent to each District but no specific instructions were given since a different interest is found in each area of the state. Therefore, one District may test only sections which are believed to be slick; another District may be interested in obtaining information on various surfacing materials which have been places; otherwise, several Districts may be interested in obtaining an inventory of the major highways within the District.

In one instance every highway was tested in the District with the exception of two or three Farm to Market pavements. With this in mind, when some statistic is given below (such as a state-wide average, this statistic may be biased or the state-wide average may not truely represent the average coefficient of the state).

In general, the tests were obtained at 40 mph in wet conditions (with the standard quantity of test water).

II. State Wide Average

From the period of May to September, 813 pavements were tested. These sections have an average coefficient of 0.39 and friction values ranging from 0.15 to 0.80 (See Figure 1). These sections include six pavement types (as offered on the code sheet), numerous coarse aggregate types, varied asphalt or cement content and aggregate gradation.

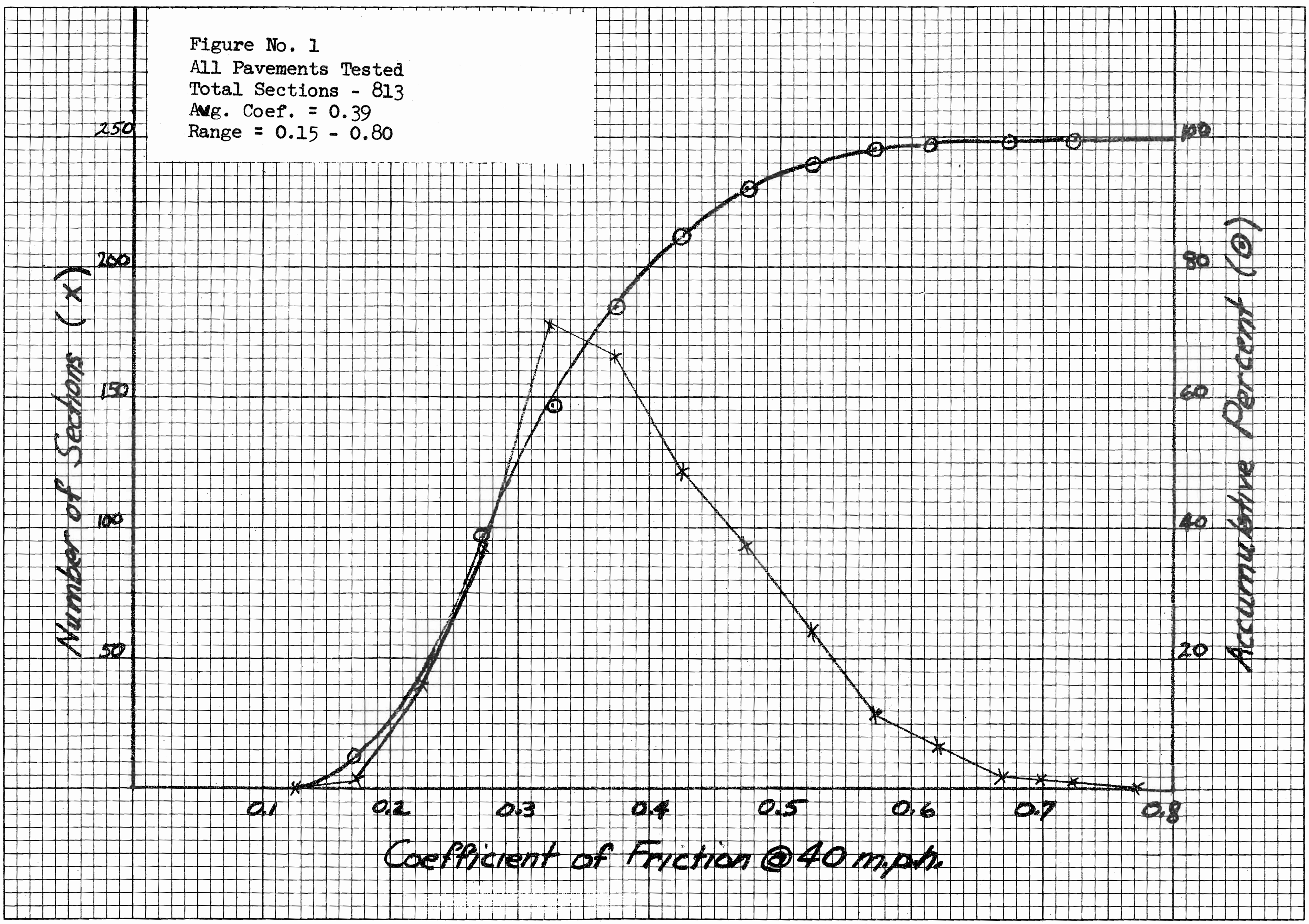


Figure No. 1
All Pavements Tested
Total Sections - 813
Avg. Coef. = 0.39
Range = 0.15 - 0.80
Number of Sections (x)
250
200
150
100
50
Accumulative Percent (⊙)
100
80
60
40
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Coefficient of Friction @ 40 m.p.h.

Surface Treatment

288 sections tested

0.38 average coefficient

0.15-0.80 range in values

(See Figure 2)

Hot Mix Asphaltic Concrete

343 sections tested

0.39 average coefficient

0.15-0.70 range in values

(See Figure 3)

Hot Mix Cold Lay - (Generally Limestone Rock Asphalt)

31 sections tested

0.39 average coefficient

0.20-0.65 range in values

(See Figure 4)

Continuously Reinforced Concrete

47 sections tested

0.40 average coefficient

0.20-0.55 range in values

(See Figure 5)

Jointed Concrete

9 sections tested

0.35 average coefficient

0.20-0.55 range in values

(See Figure 6)

Slurry Seals

6 sections tested

0.36 average coefficient

0.20-0.65 range in values

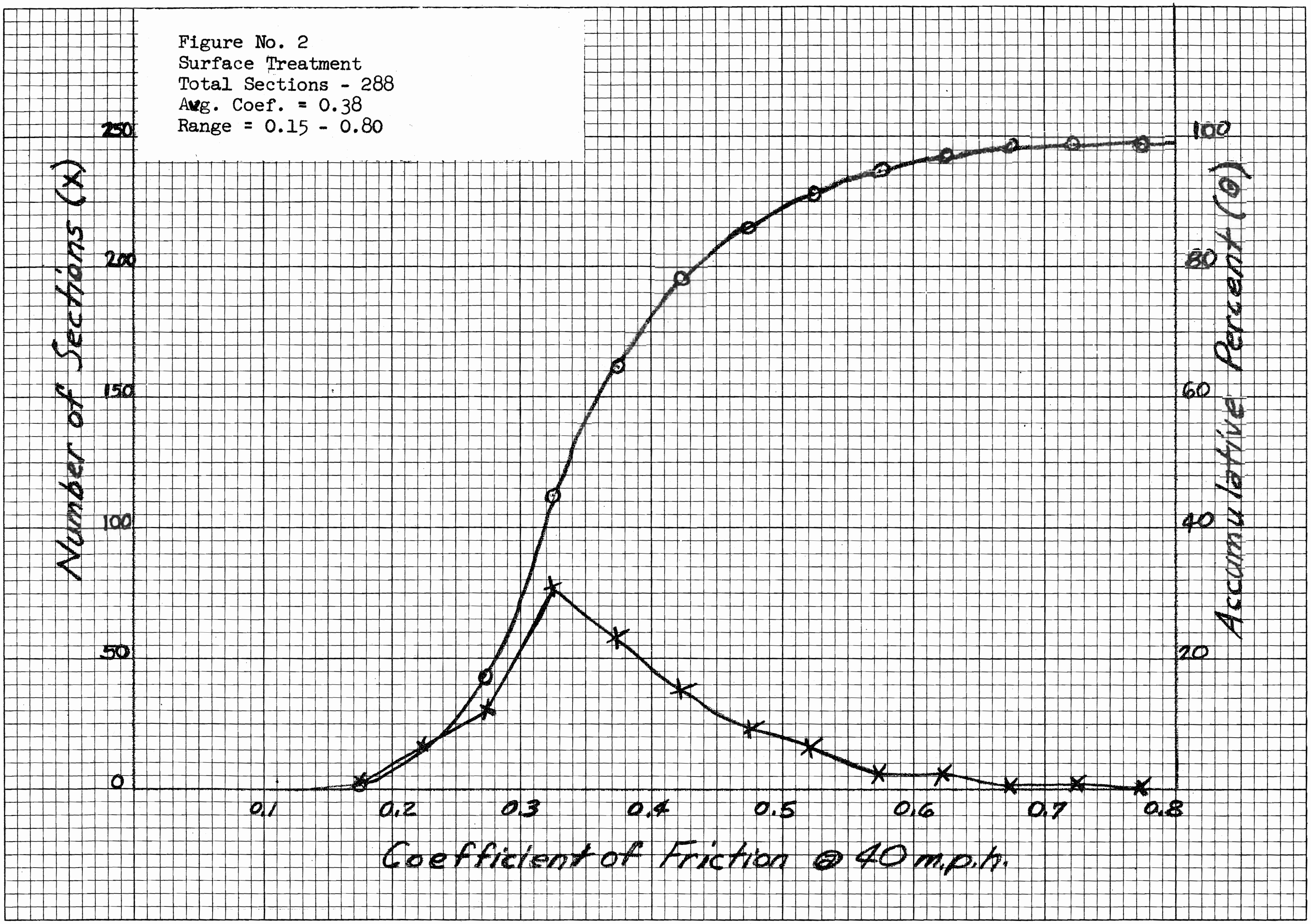


Figure No. 2
Surface Treatment
Total Sections - 288
Avg. Coef. = 0.38
Range = 0.15 - 0.80

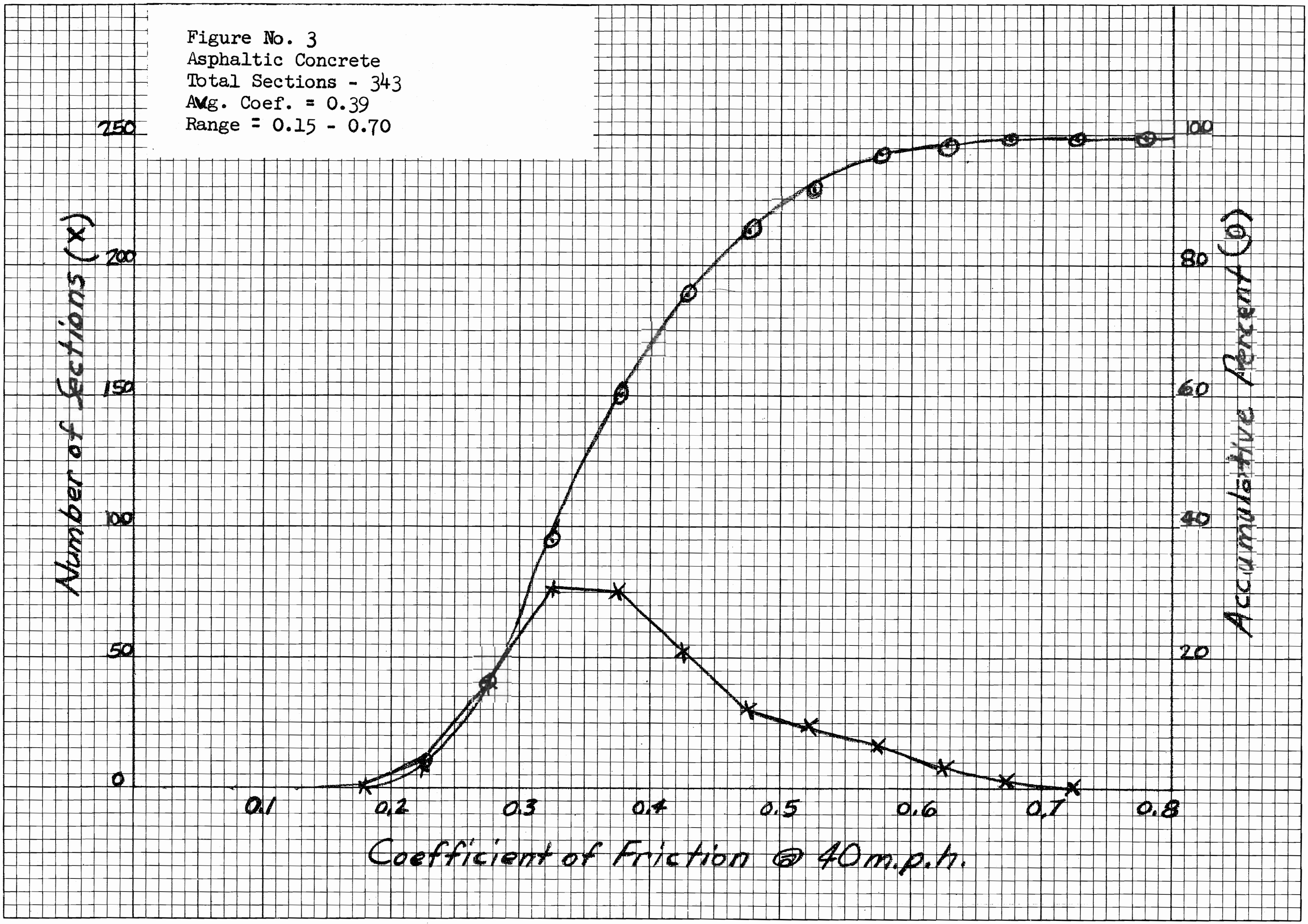


Figure No. 3
Asphaltic Concrete
Total Sections - 343
AWg. Coef. = 0.39
Range = 0.15 - 0.70
Number of Sections (x)
Accumulative Percent (o)
250
200
150
100
50
0
100
80
60
40
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Coefficient of Friction @ 40m.p.h.

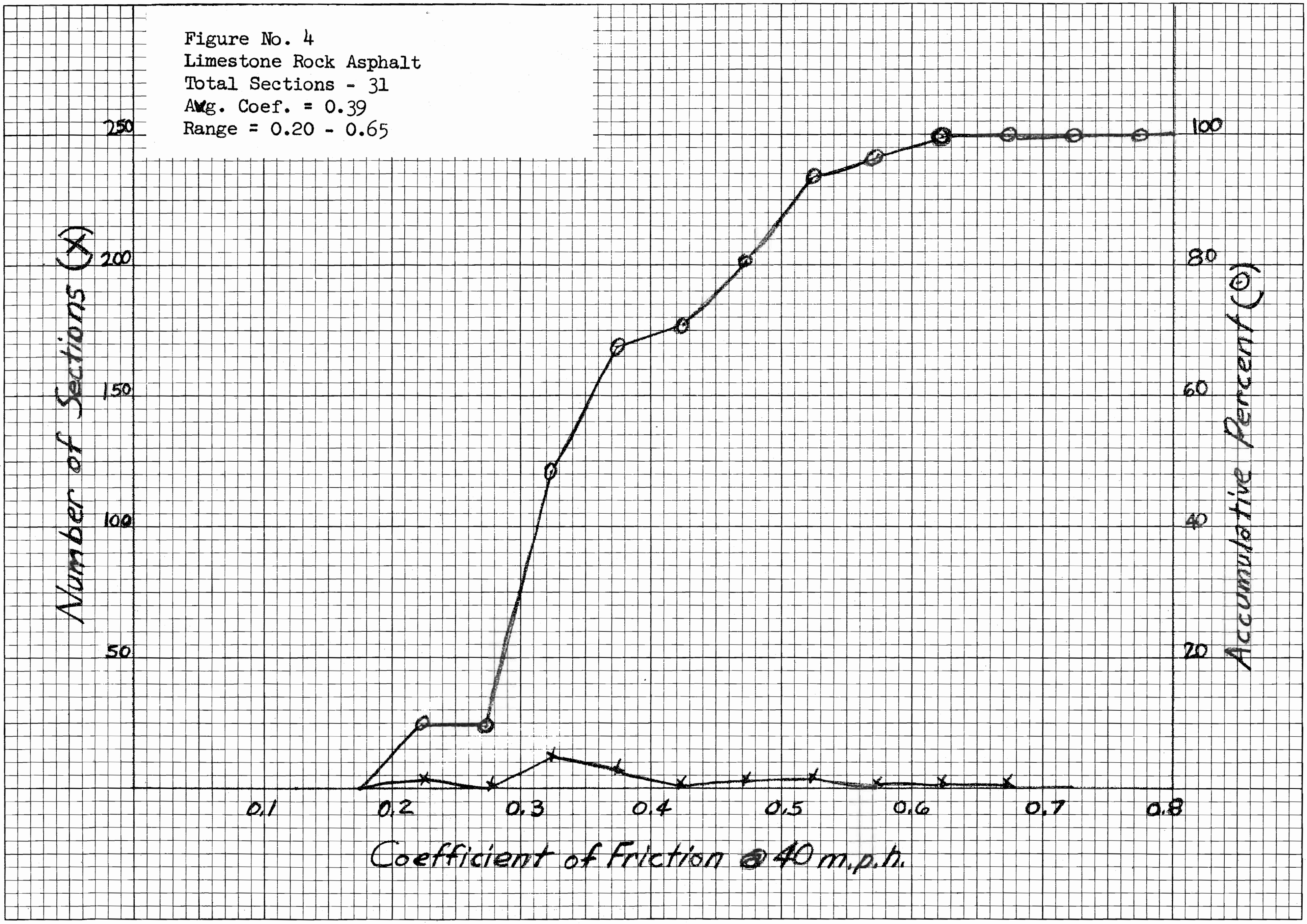


Figure No. 4
Limestone Rock Asphalt
Total Sections - 31
Avg. Coef. = 0.39
Range = 0.20 - 0.65
Number of Sections (X)
250
200
150
100
50
Accumulative Percent (⊙)
100
80
60
40
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Coefficient of Friction @ 40 m.p.h.

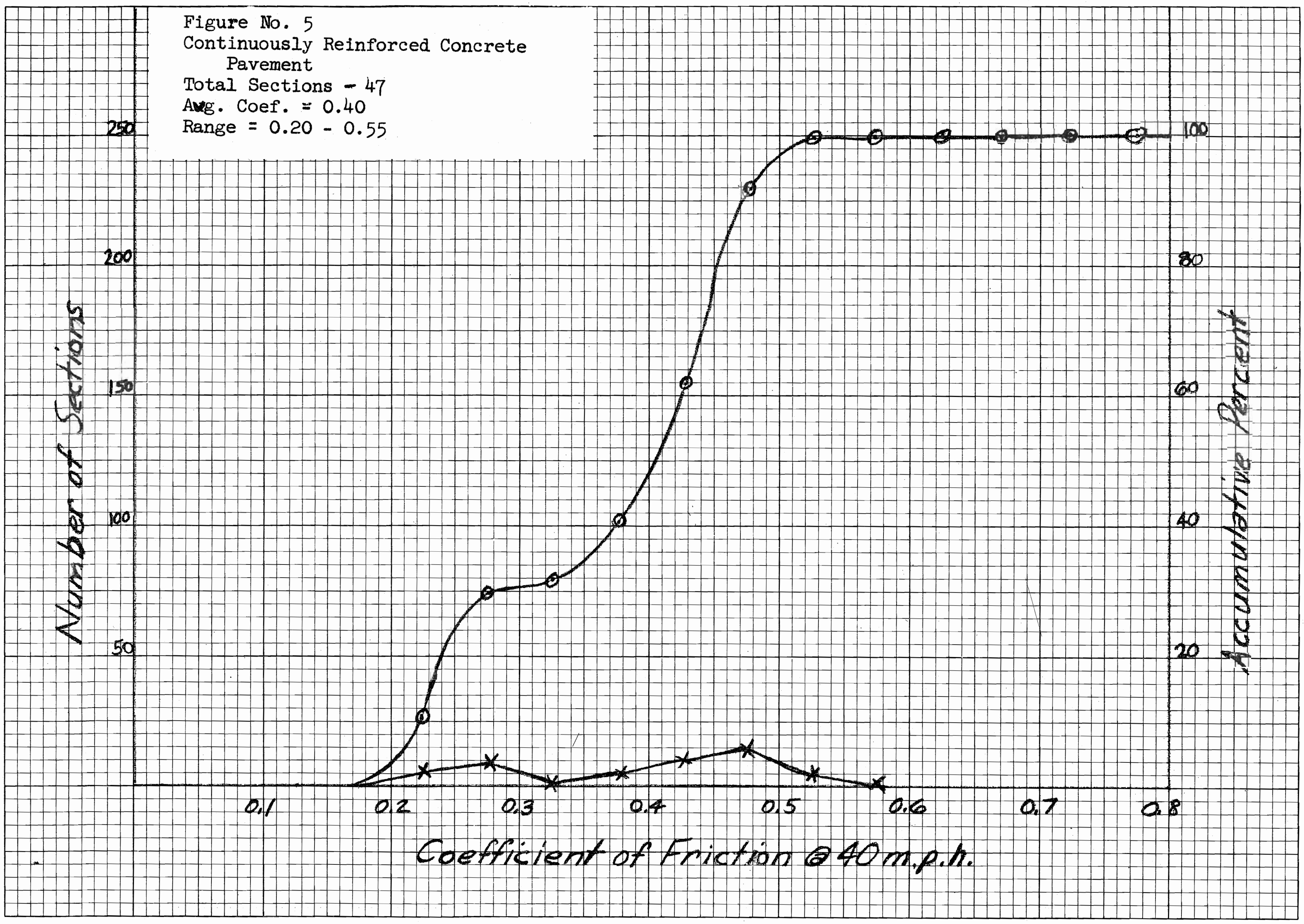


Figure No. 5
Continuously Reinforced Concrete Pavement
Total Sections - 47
Avg. Coef. = 0.40
Range = 0.20 - 0.55

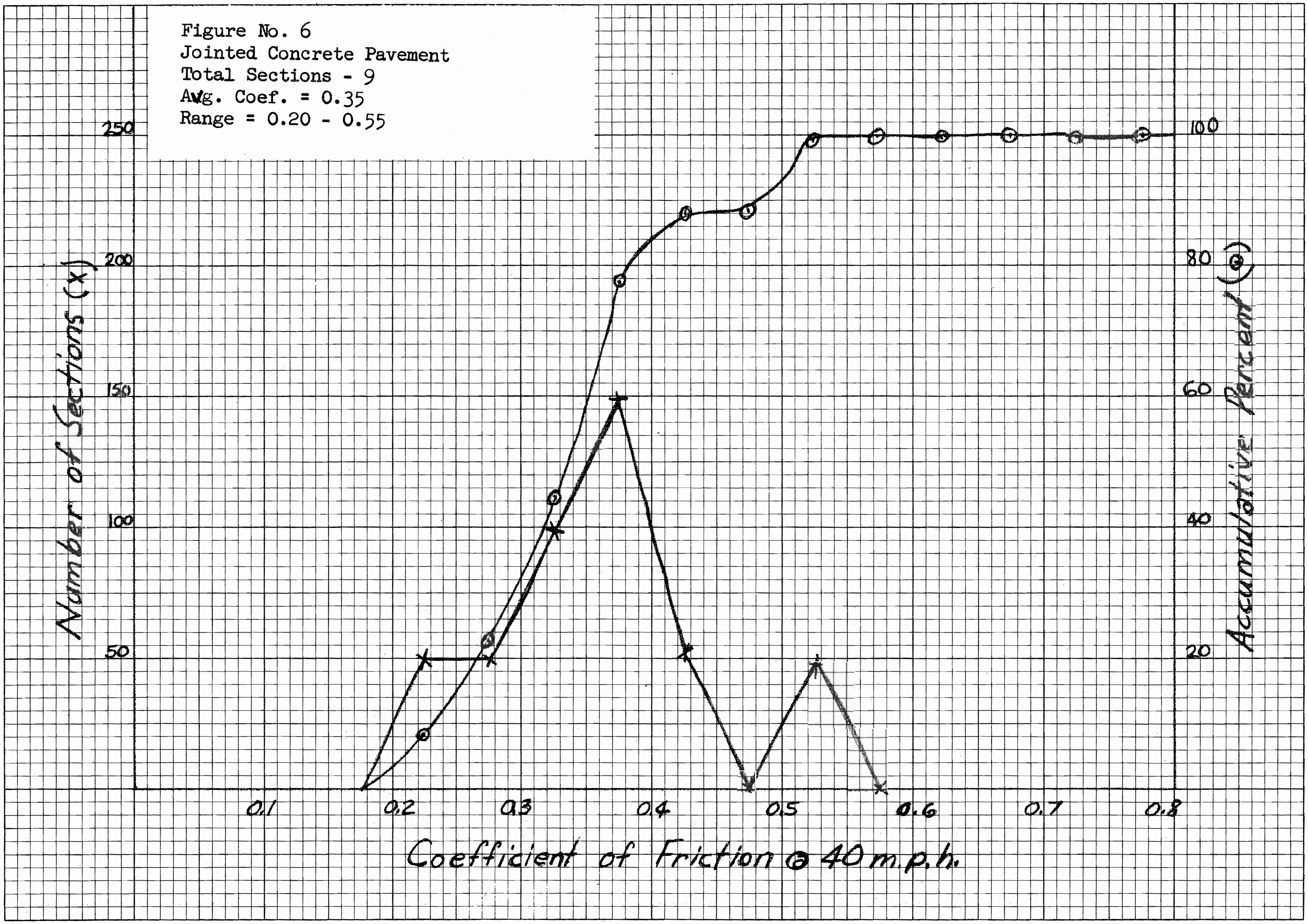


Figure No. 6
Jointed Concrete Pavement
Total Sections - 9
Avg. Coef. = 0.35
Range = 0.20 - 0.55

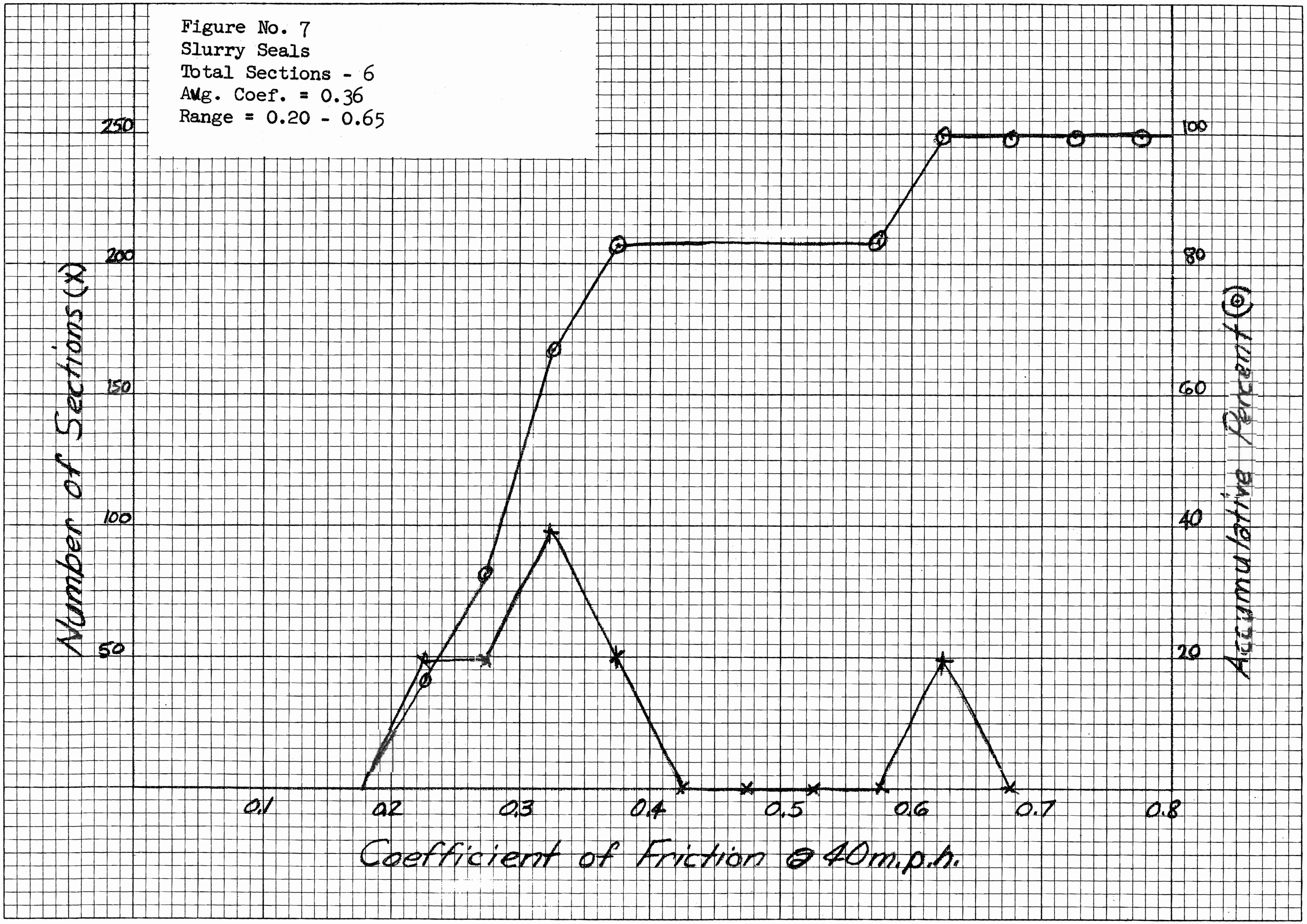


Figure No. 7
Slurry Seals
Total Sections - 6
Avg. Coef. = 0.36
Range = 0.20 - 0.65

Table I reveals general information items of several material types used in both Asphaltic Concretes and Surface Treatments. This table, of course, reveals nothing of the wear or duration properties of the materials since traffic has not been considered. The "Stan. Dev." is the standard deviation which is also a measure of the <u>range</u>.

TABLE I

STUDY OF AGGREGATE MATERIAL TYPES

MATERIAL TYPE	HMAC				SURFACE TREATMENT			
	Aver. Coef	Stan. Dev.	Range	No. Tested	No. Tested	Aver. Coef.	Stan. Dev.	Range
SHELL	.30	.08	.20-.55	20				
LIME ROCK ASP.	.35	0.11	.25-.60	10	32	.43	0.08	.25-.55
ALCOA SLAG	.39	0.07	.25-.70	72				
LIMESTONE	.42	.10	.25-.70	88	49	.38	0.09	.15-.65
SILICEOUS	.44	.12	.20-.70	51	100	.34	.05	.20-.60
LIGHT WEIGHT	.45	.03	.40-.50	4	16	.47	0.09	.30-.65
IRON ORE SLAG	.47	.06	.35-.60	11	25	.56	.14	.25-.80

III. Wear Curves

The following plots are an attempt to study pavement materials (in relation to skid resistance) more closely. The code sheets which are filled out or completed by the District have been designed so that the District observer may purposely omit several items related to materials. It was believed that the District would desire to keep such records but there would be occasion in which District personnel would not have time to complete the material and traffic items (which require an extensive back search in many cases). However, once complete, little work would be necessary to keep the records up-to-date, since it would only require copying data from the output sheet of a previously tested section on the event of future testing. Of course, if a section had been overlaid between test periods, it will be necessary to place on the code sheet the new surface material information which should be easily available.

A measure of the number of vehicles which has worn or polished a section has been obtained by determining the "number of days since placement" and multiplying this value by the ADT (called "Total Traffic"). The "number of days since placement" was obtained by determining the number of days between the "date the surface was placed" and the "date of test" both of which appear on the code sheet. This is not the best measure of the traffic which has polished a pavement but other values would require much more coding, and back search. The measure of "Total Traffic" which is used in this report is believed to be sufficient to determine wear characteristics of surfacing materials and methods.

The following plots were obtained from the information which was completed by the Districts. In many cases all information was not available. The curves shown have been placed by eye through the average condition hopefully to assist the reader.

Surface Treatment

Figure 8 is a plot of all surface material types used in a surface treatment. Figures 9 through 11 are plots of several coarse aggregate materials used in surface treatments. The data points are widely scattered, but tend to show the coarse aggregate influences the coefficient of friction.

With the exception of the initial wear, the wear rate is approximately the same for each coarse aggregate material type. However, it may be noted that for any one time period (traffic range) each material has a significantly different range in coefficient values. (Please note - the traffic scale for lightweight is different than for the limestone or siliceous materials).

Hot Mix Asphaltic Concrete

Figure 12 is a general plot of all HMAC sections. Figures 13, 14, 15 and 16 are plots in which the coarse aggregate material types have been studied.

Again a wide scatter is found, but the general trend shows that limestone generally has higher coefficients than siliceous or aluminum slag, however, surfaces with limestone aggregate can be as low as those with siliceous or aluminum slag material. There was one project using Burned Clay coarse aggregate which resulted in 0.46 with 4,087,000 traffic applications.

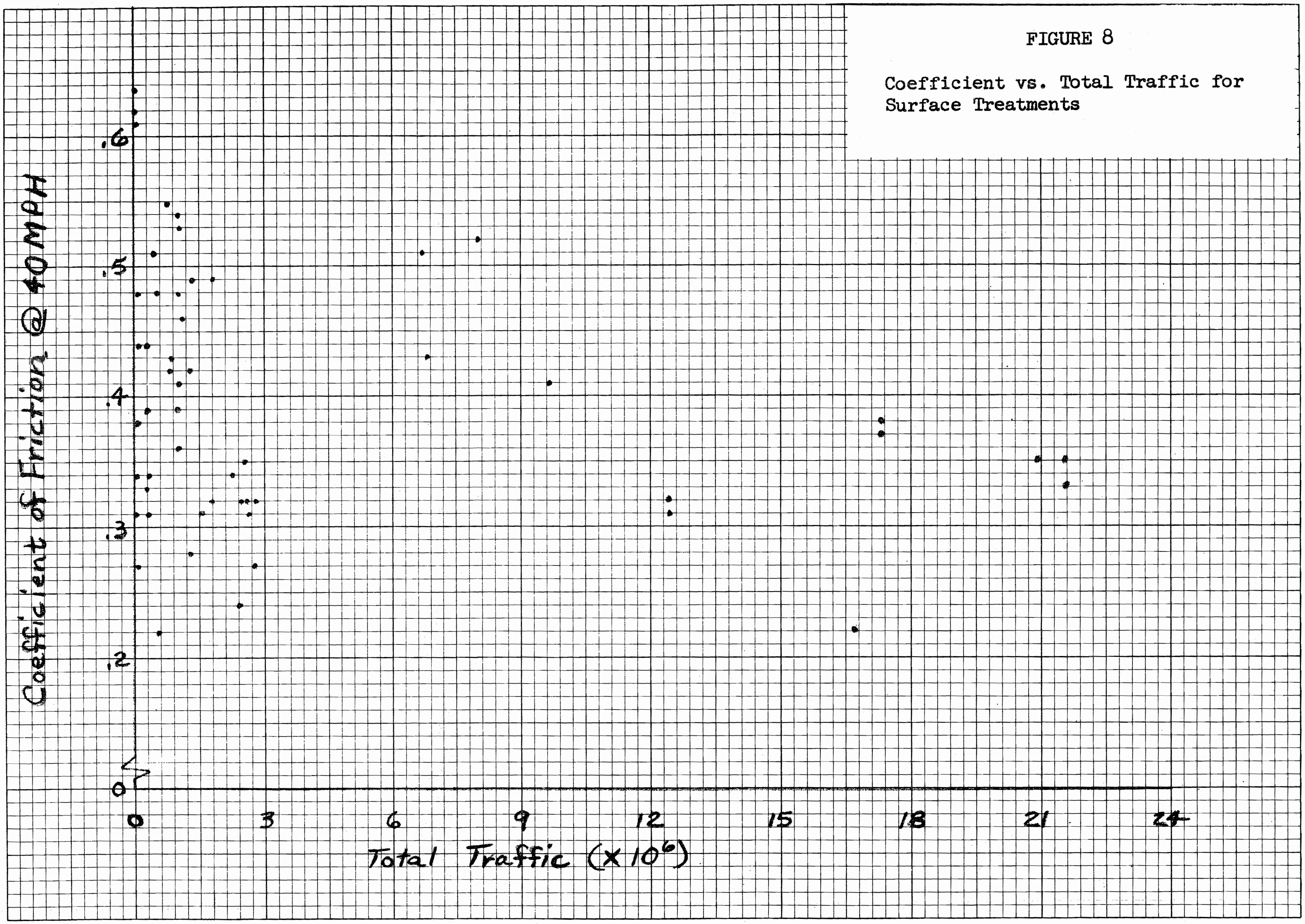


FIGURE 8

Coefficient vs. Total Traffic for Surface Treatments

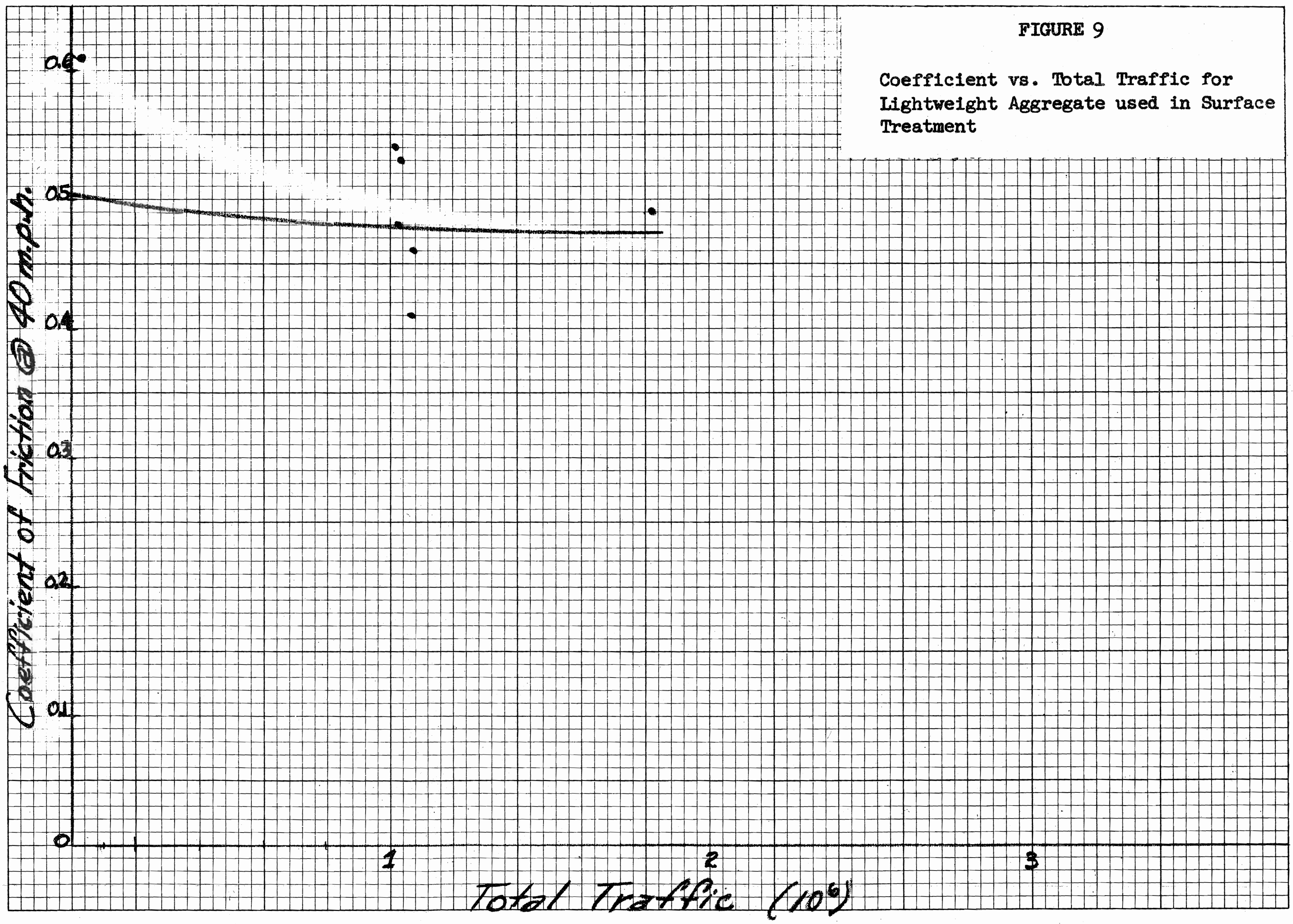


FIGURE 9

Coefficient vs. Total Traffic for Lightweight Aggregate used in Surface Treatment

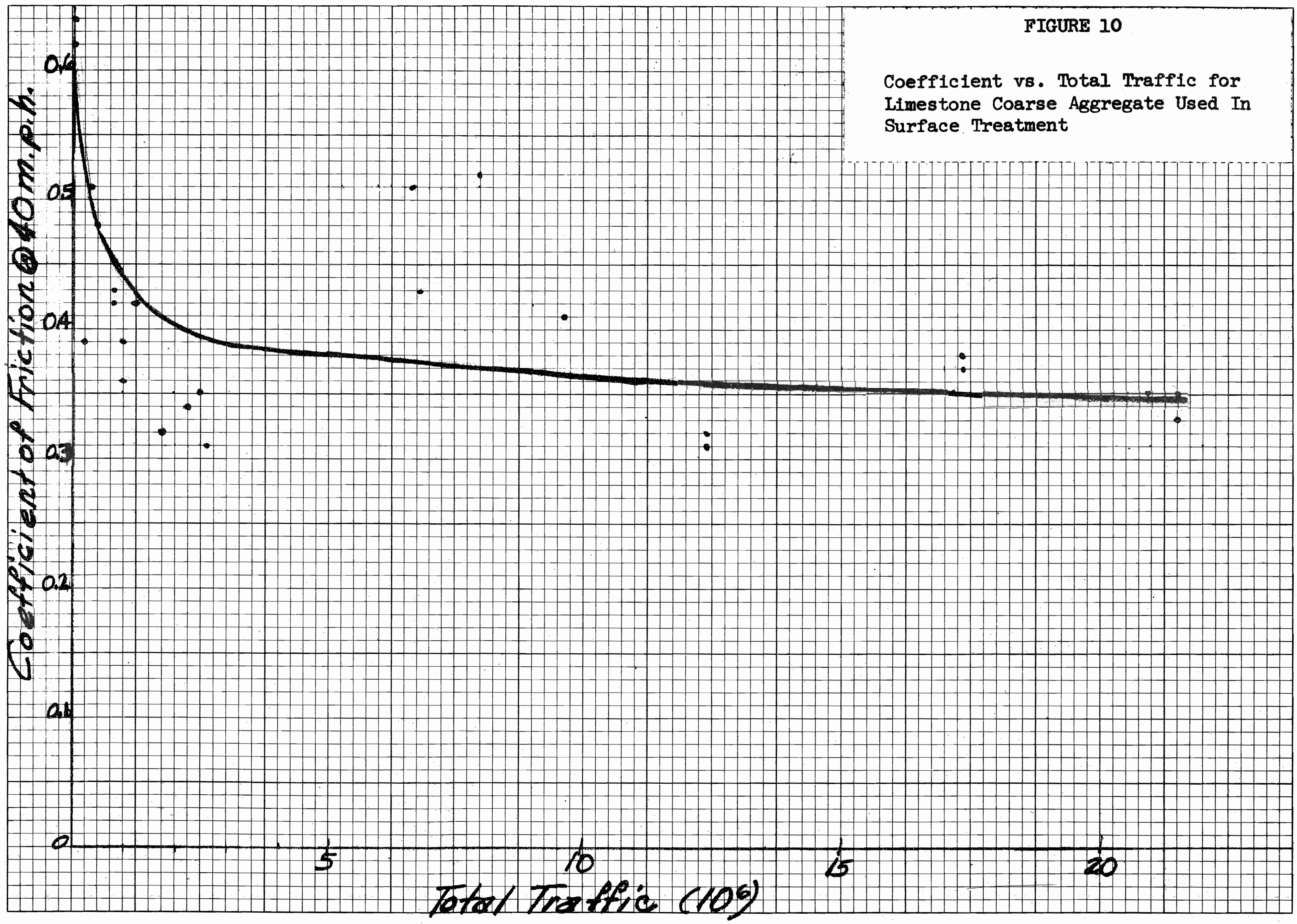


FIGURE 10

Coefficient vs. Total Traffic for Limestone Coarse Aggregate Used In Surface Treatment

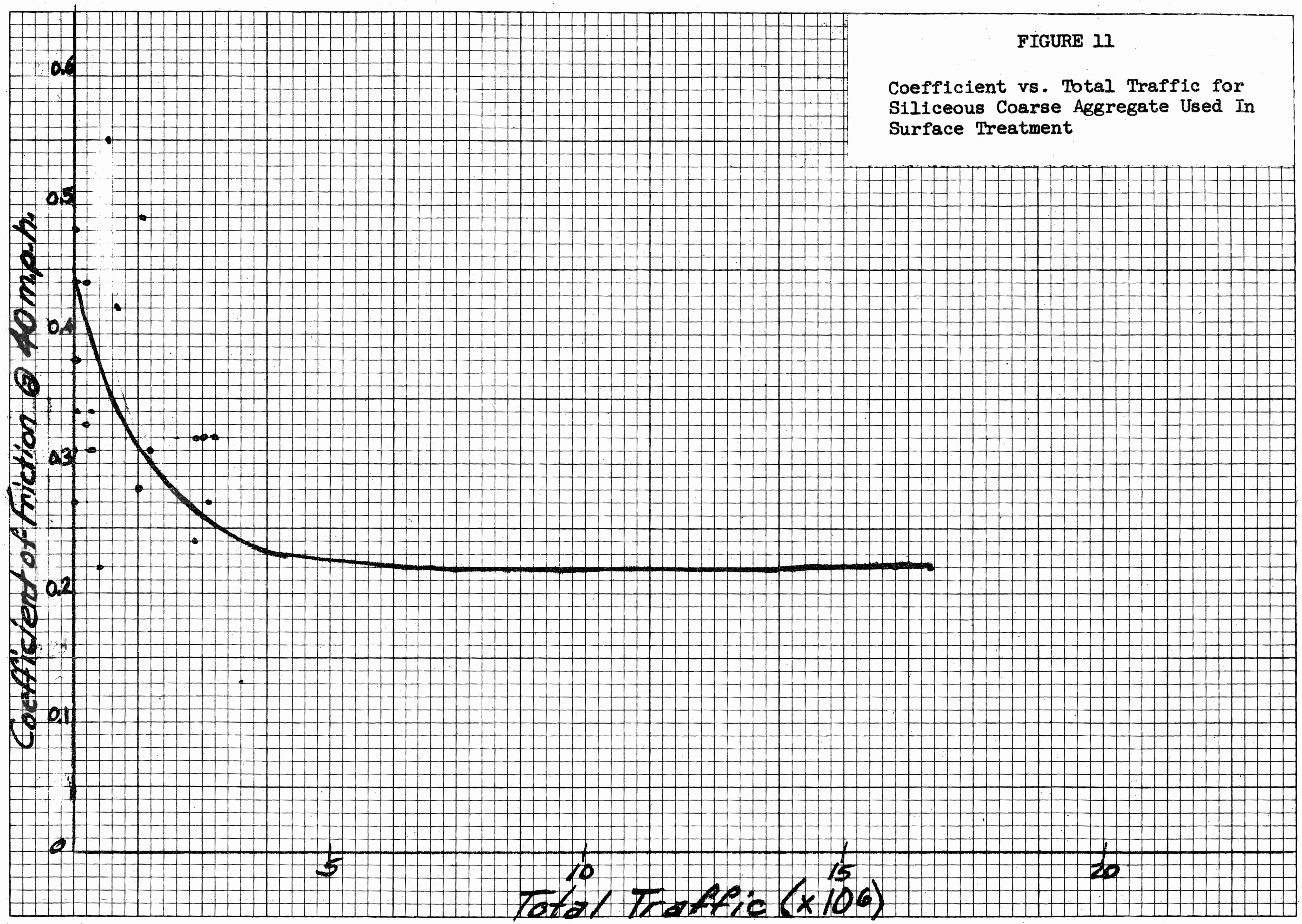


FIGURE 11

Coefficient vs. Total Traffic for Siliceous Coarse Aggregate Used In Surface Treatment

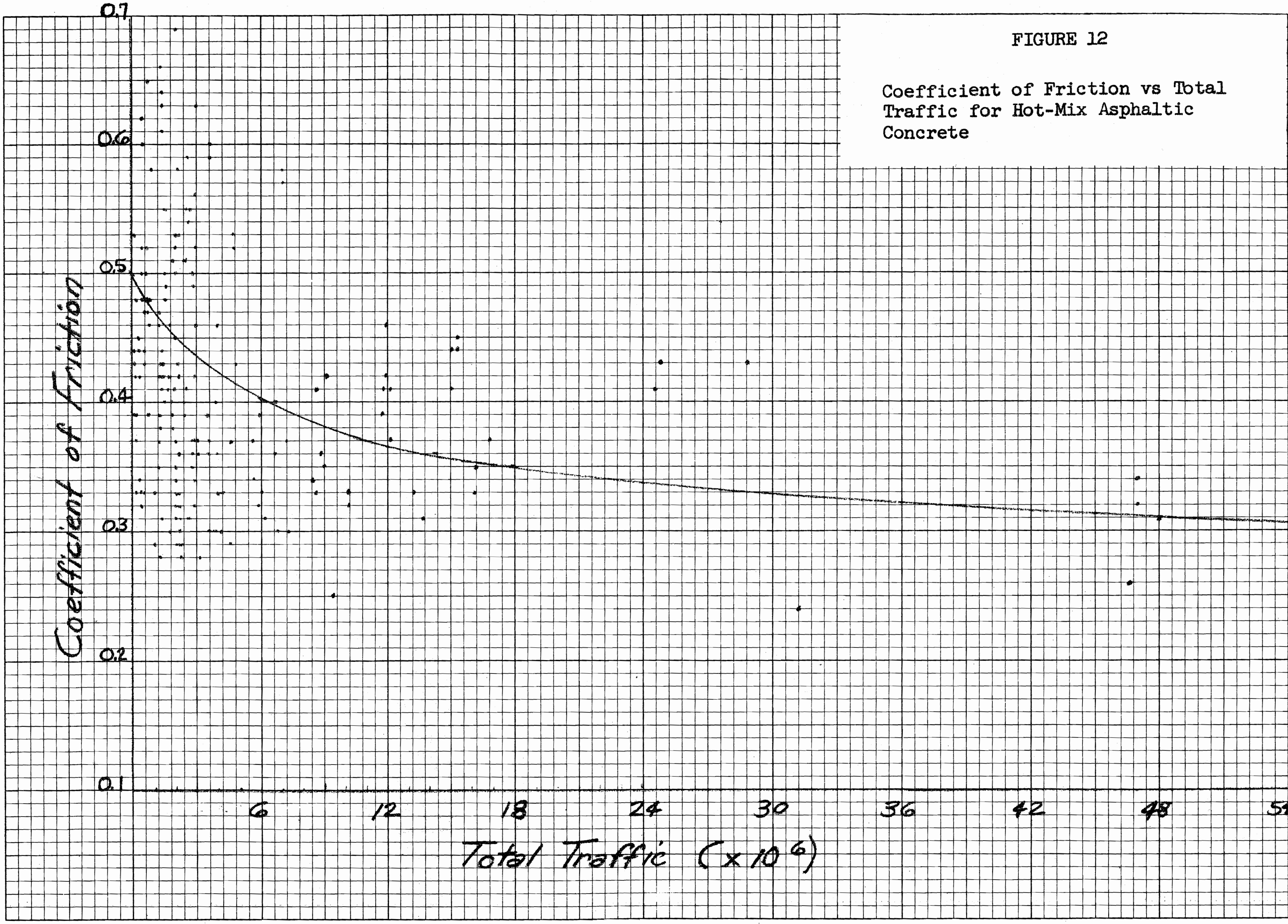


FIGURE 12

Coefficient of Friction vs Total Traffic for Hot-Mix Asphaltic Concrete

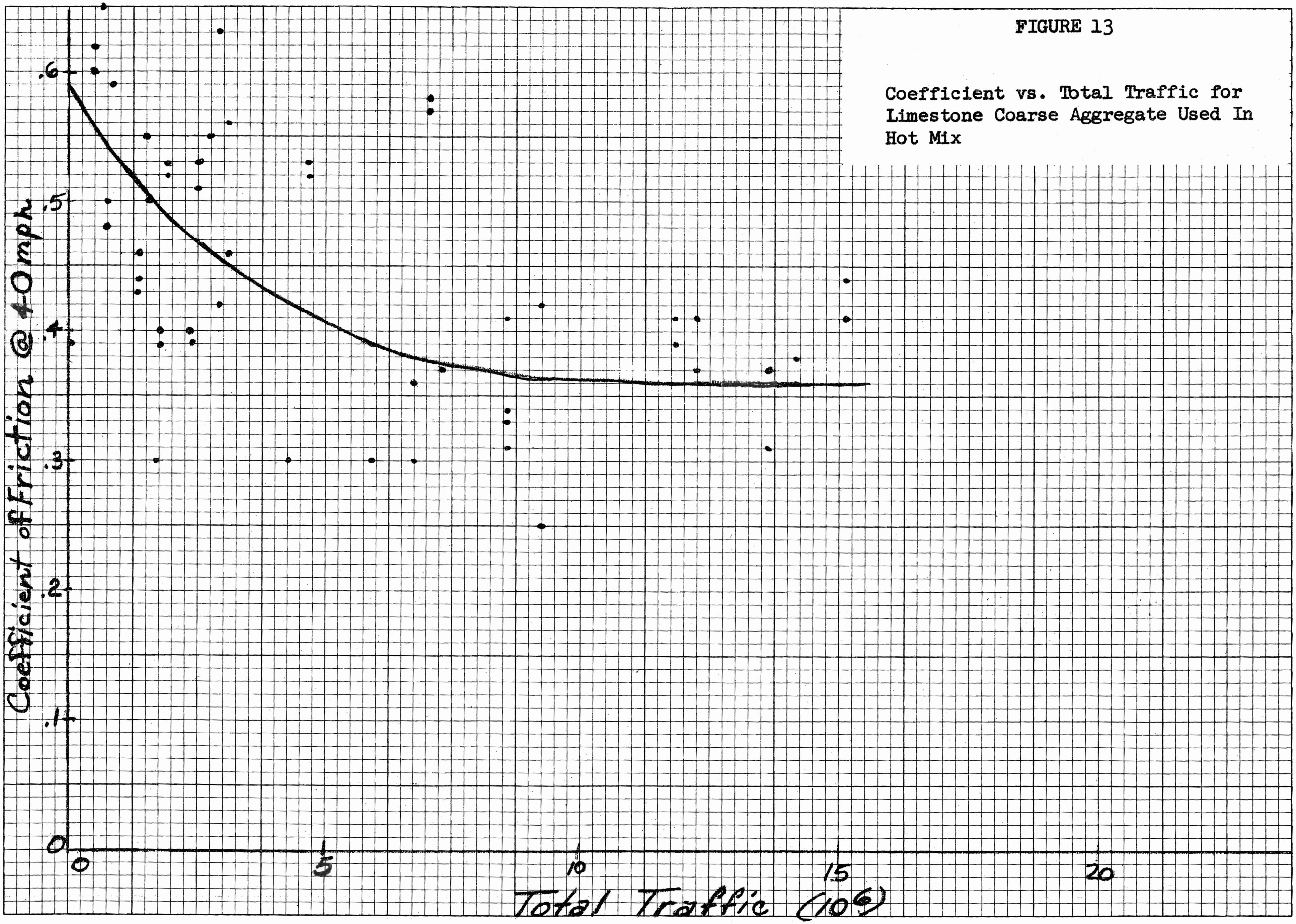


FIGURE 13

Coefficient vs. Total Traffic for Limestone Coarse Aggregate Used In Hot Mix

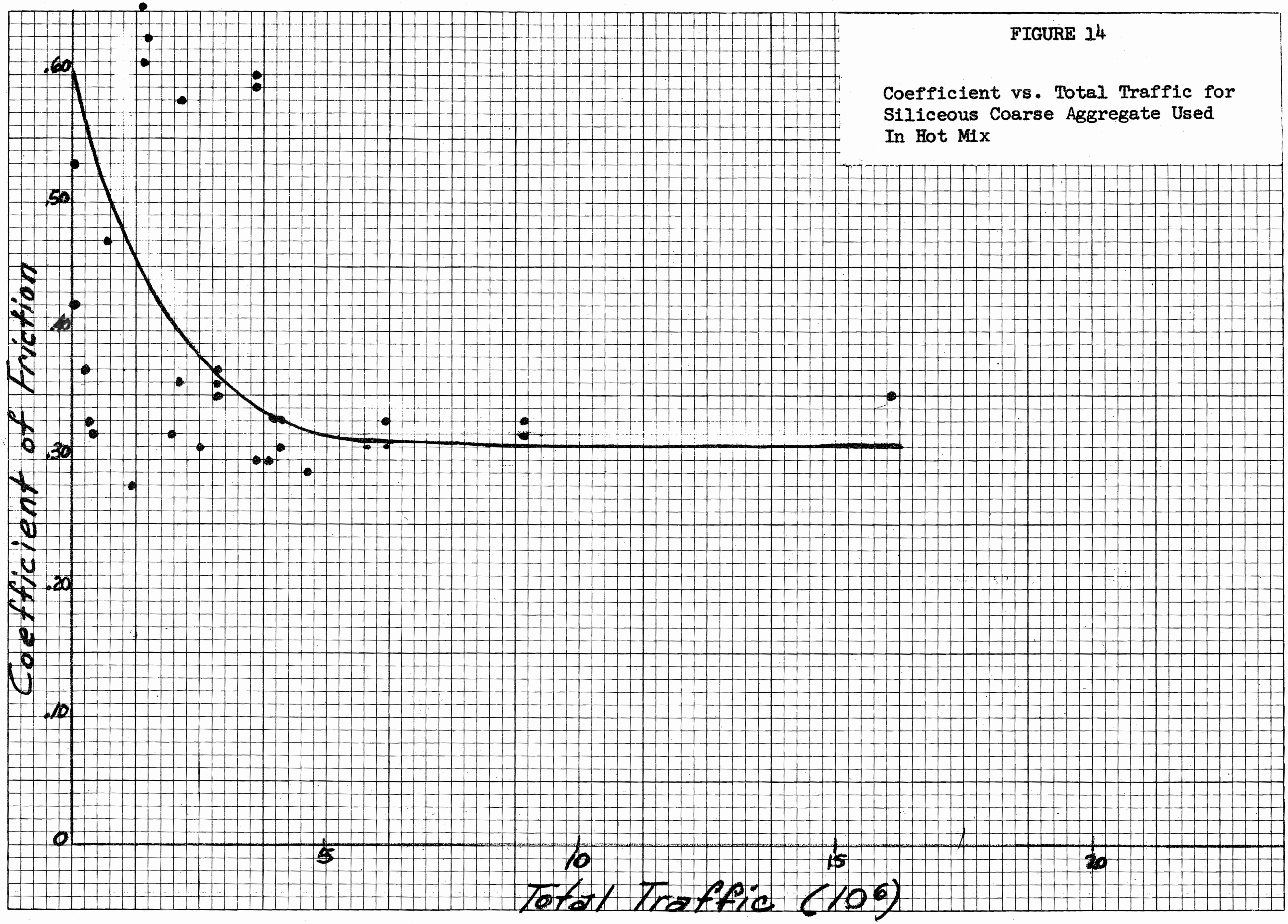


FIGURE 14

Coefficient vs. Total Traffic for Siliceous Coarse Aggregate Used In Hot Mix

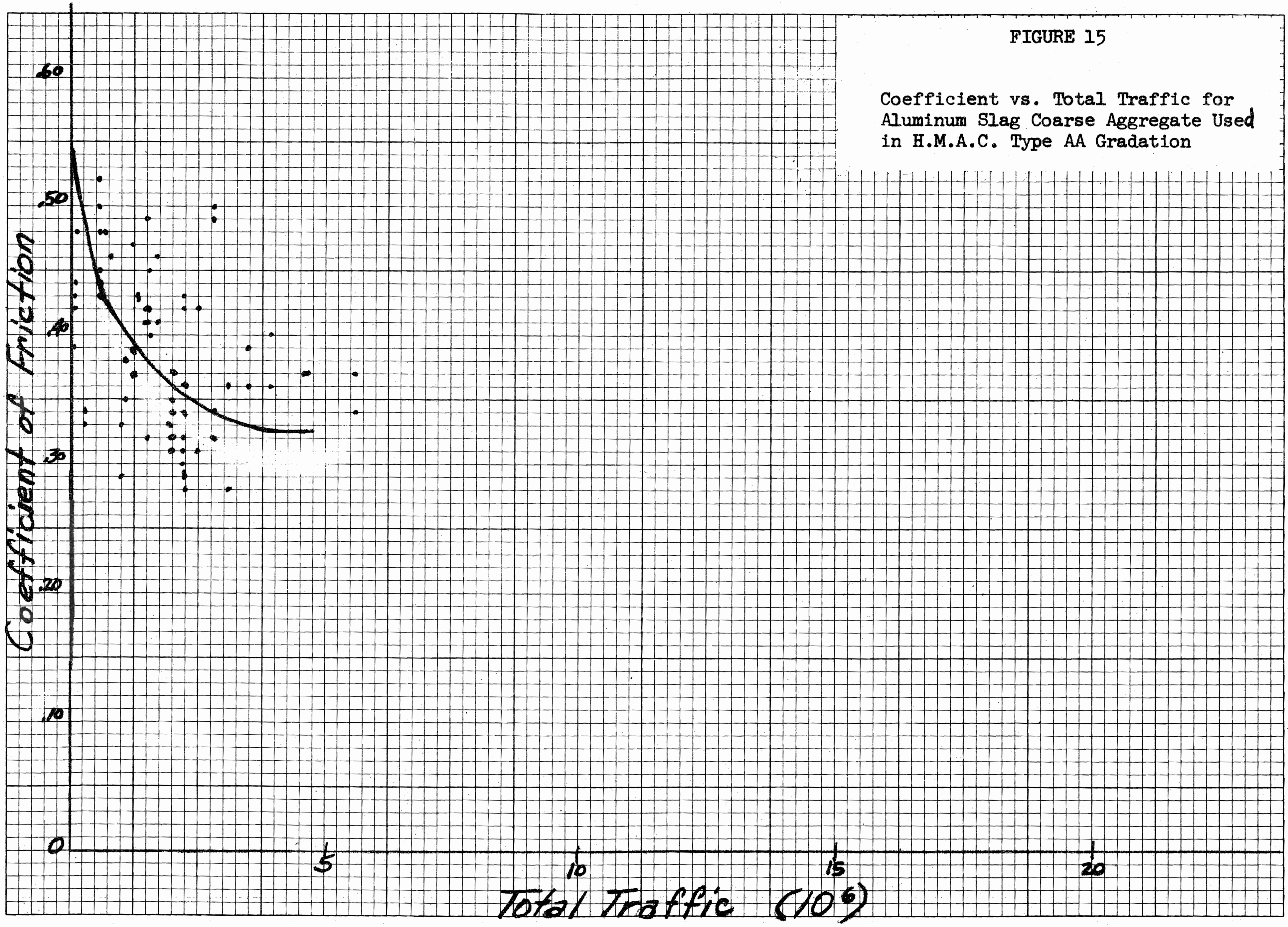


FIGURE 15

Coefficient vs. Total Traffic for Aluminum Slag Coarse Aggregate Used in H.M.A.C. Type AA Gradation

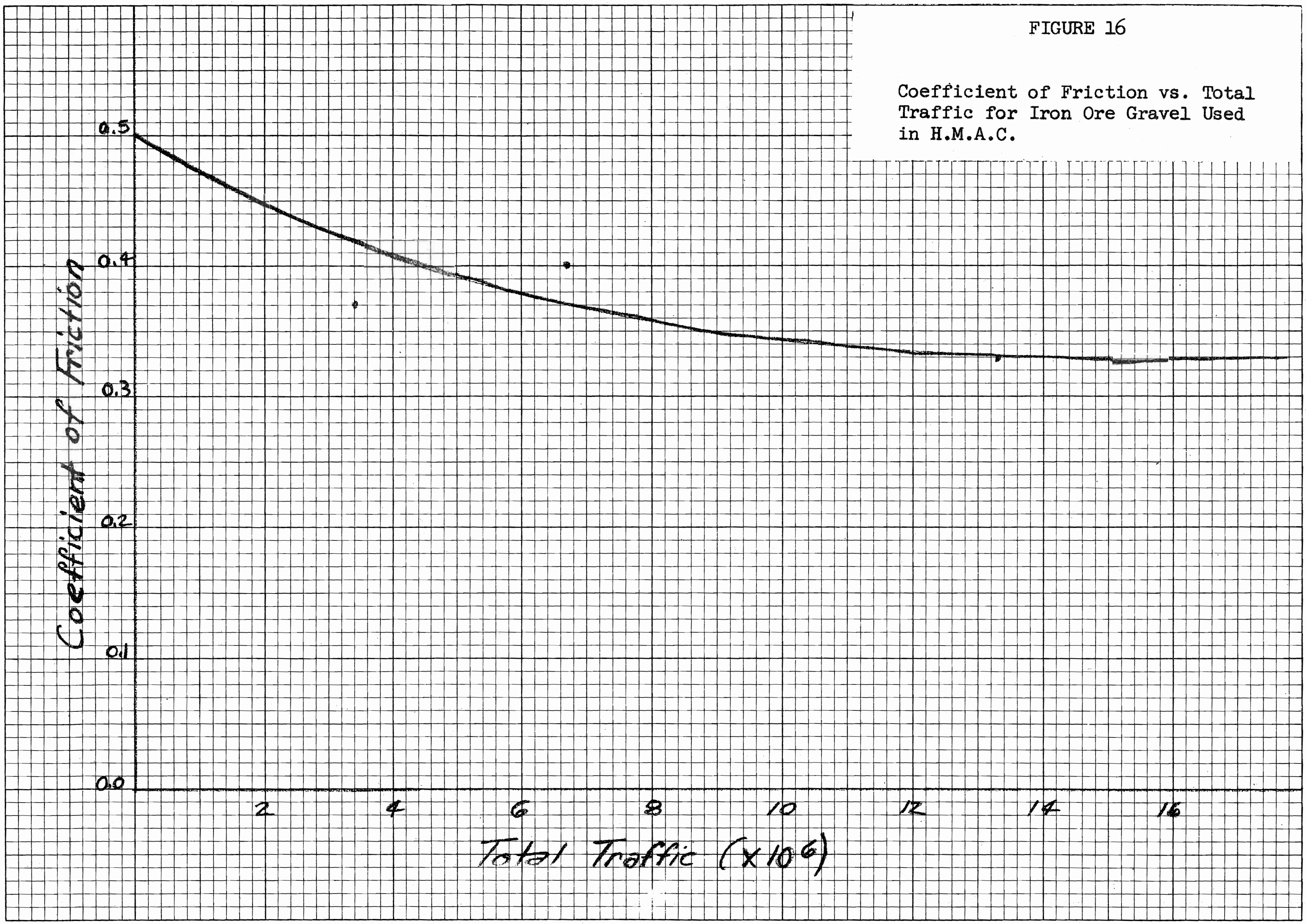


FIGURE 16

Coefficient of Friction vs. Total Traffic for Iron Ore Gravel Used in H.M.A.C.

Continuously Reinforced Concrete Pavement

Very little traffic data was available from the completed tests. The plot in Figure 17 indicates that only two pavements have been tested. Little judgement and on conclusions can be obtained from this information.

Slurry Seals

The few data points available in Figure 18 would indicate a rapid and continued wear (loss of coefficient of friction) regardless of the coarse aggregate material type. In general, the coarse aggregate material was Limestone Rock Asphalt.

Hot Mix Cold Laid Asphaltic Concrete

Again the small number of data points in Figure 19 makes analysis difficult. The range in friction values in the 4-6 million traffic range (0.23 to 0.52 or a range of approximately 0.30) would indicate pavements can be constructed with high friction values, but because of other factors (possibly bleeding, soft aggregate, etc) pavement surfaces can have low values also. Because of the 0.3 range at 4-6 million applications of traffic, the same range could be expected at the data point at approximately 19 million applications. The one data point (at 19 million) could be on the high side of the 0.3 range, around the middle of the range, or on the low side of the range. Since almost no values have been found below 0.20 (which is the value of a bleeding surface with no aggregate protruding) it is suspected that the one data point at 19 million applications is on the low side of the range and values could be as high as 0.50 at 19 million applications. The same theory could be used on the other plots.

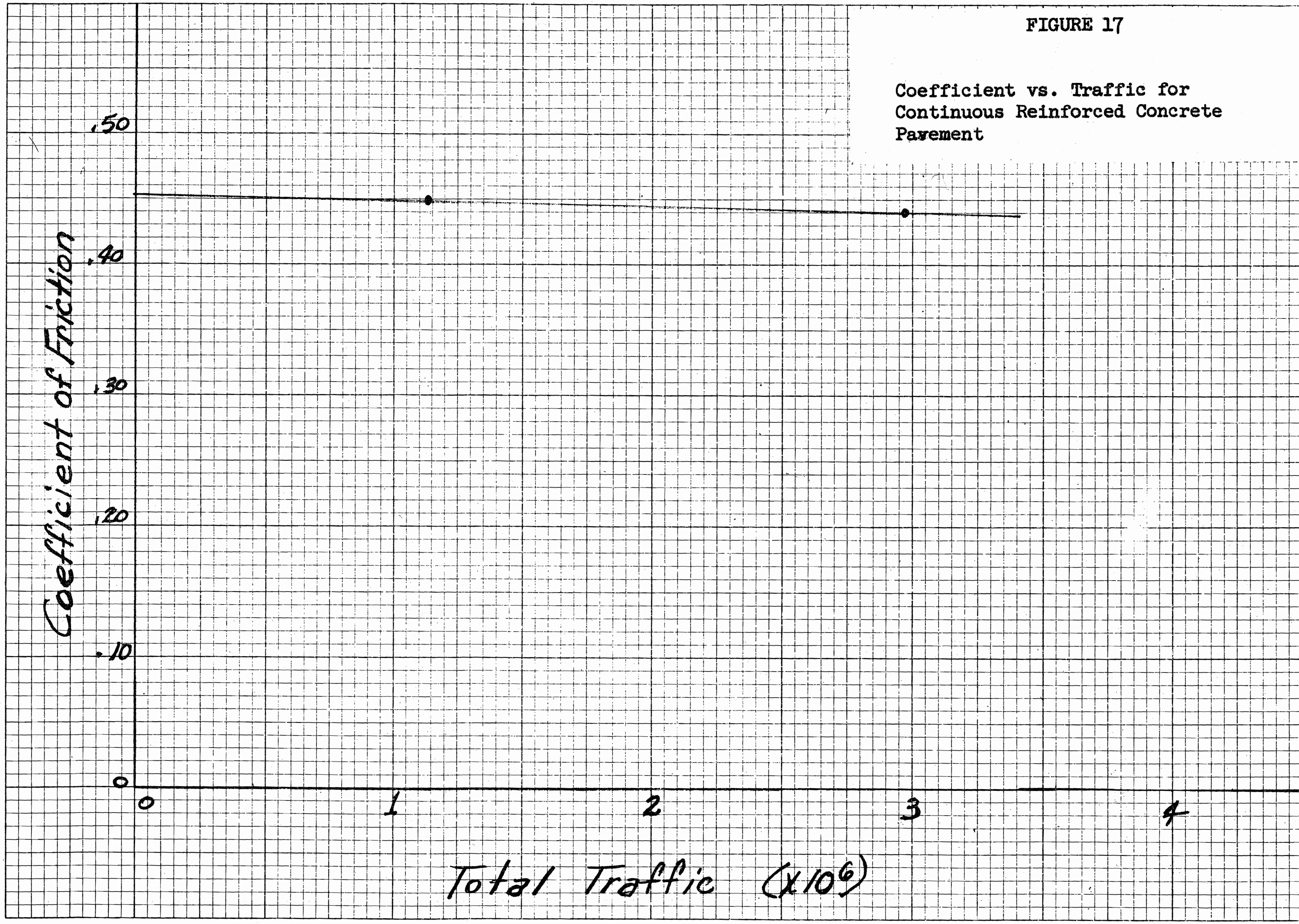
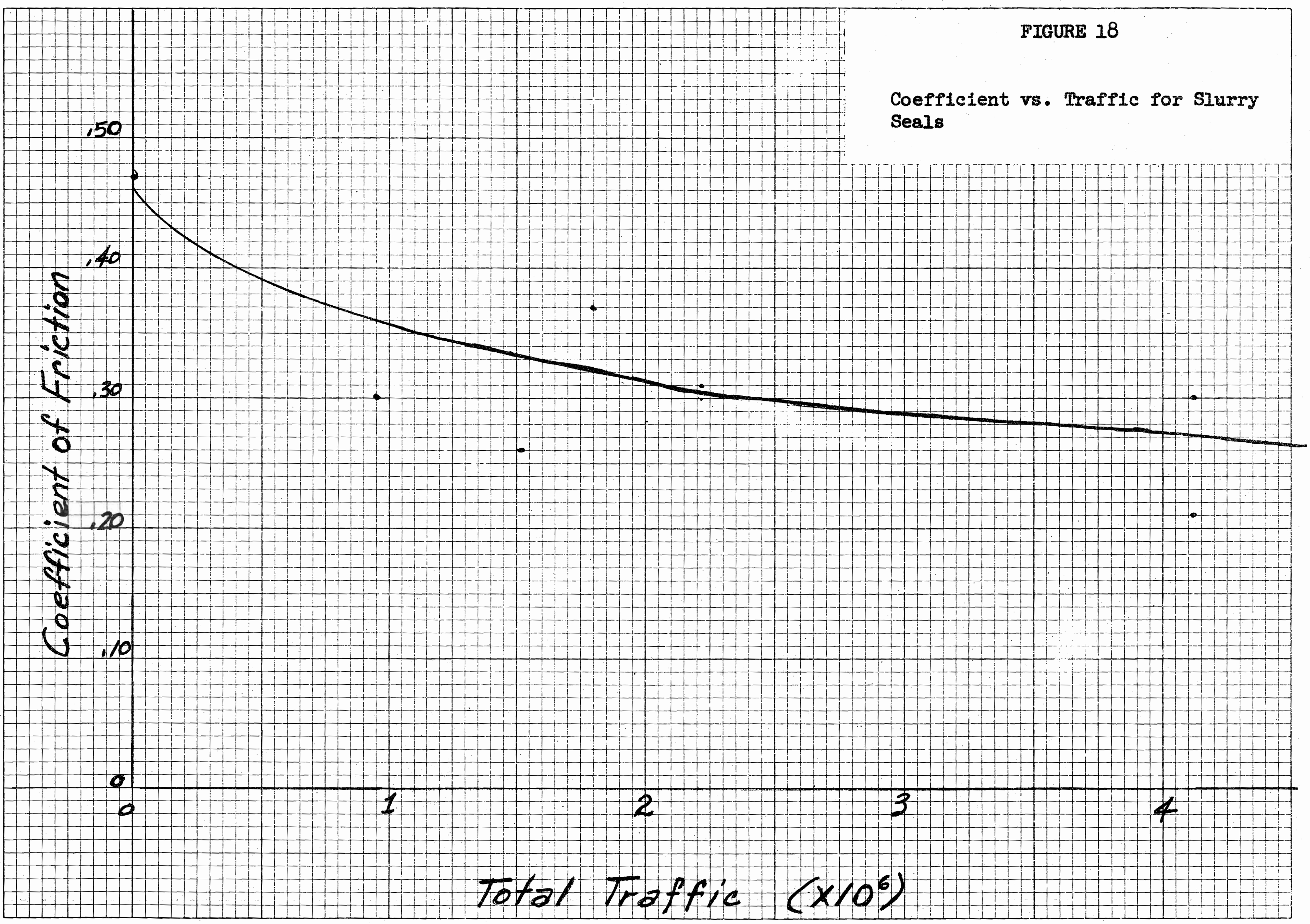


FIGURE 17

Coefficient vs. Traffic for Continuous Reinforced Concrete Pavement

FIGURE 18

Coefficient vs. Traffic for Slurry Seals



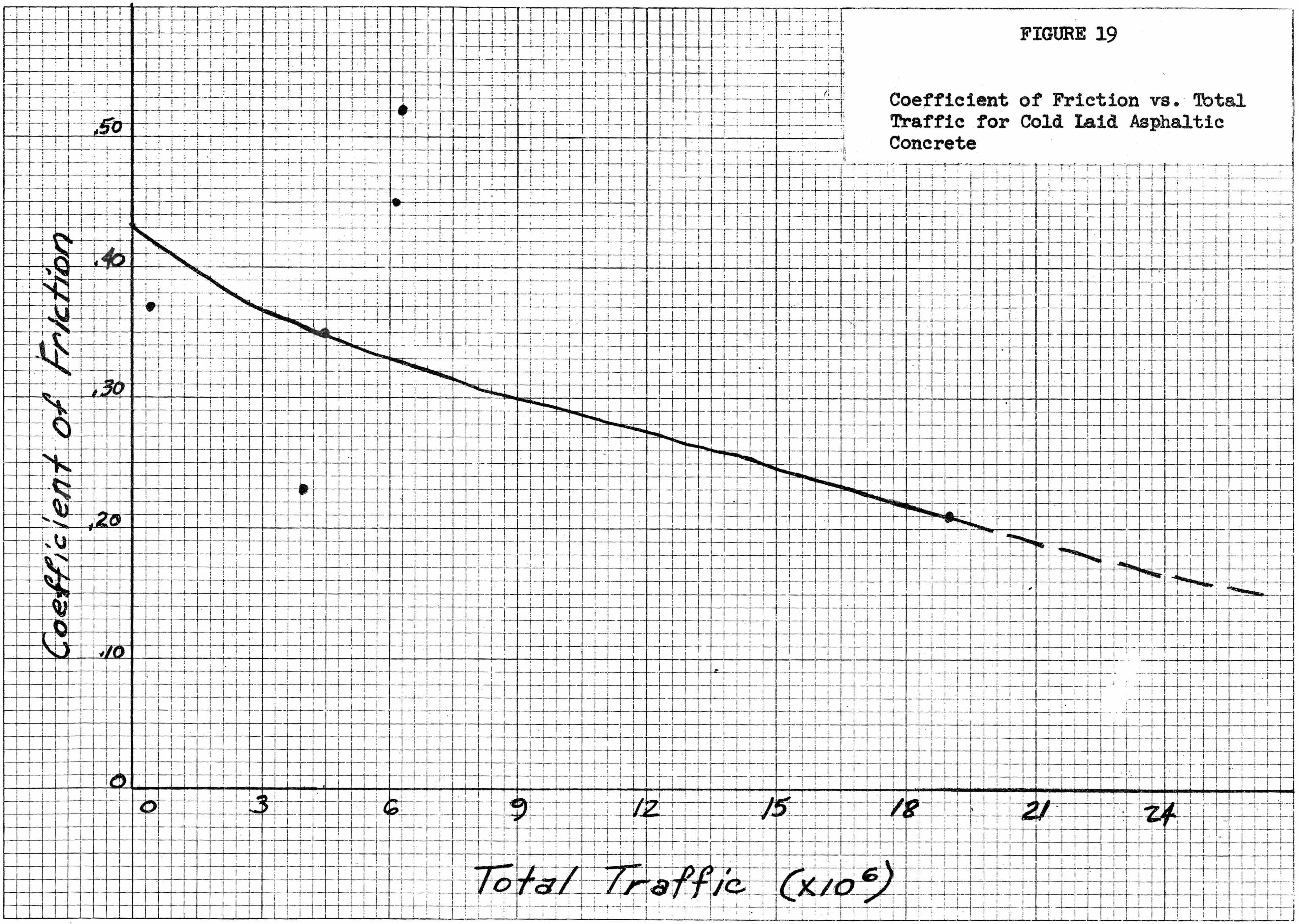


FIGURE 19

Coefficient of Friction vs. Total Traffic for Cold Laid Asphaltic Concrete

IV. Pavement Material

The following plots were obtained in an attempt to study the surfacing materials even more closely. The dominating influence of the loss in friction with increased traffic is of course the quantity (and Type) of the traffic. It was noted that when the coefficient was plotted V.S. the traffic there was a range in coefficient values after a coarse aggregate material of the same type had received approximately the same amount of traffic. Why this range in values? Possibly it is because of the amount of binder (asphalt) or the size of aggregate used on any one pavement. Or possibly it results from some construction practice or other variable as yet unknown or unmeasured. In this study the gradation and binder content were obtained at a selected traffic range for a given material and pavement type. The following plots indicate the effect of gradation and binder content on the friction values at the selected traffic ranges for various materials and pavement types.

The analysis has been broken down into a study of (1) the binder and (2) the gradation. The first figure of any series is usually a general plot of all information obtained for a pavement type followed by specific information of the material types used in the pavement type.

The Effect of Binder

Hot Mix Asphaltic Concrete Without the actual information about the mix design, analysis is generally made by studying the effect while keeping in mind the major facts about the HMAC type and aggregate material used. That is, Type D-HMAC has a smaller size material than Type C, Limestone aggregate generally absorbs more asphalt than Siliceous, the mix using the smaller sizes of aggregate would probably require more asphalt, etc.

Two traffic ranges were selected for HMAC, these being (1) 0-4 million applications and (2) 4-8 million applications. It should be remembered that the ADT was used in this analysis and therefore all traffic in all lanes and in both directions.

Most authorities agree that aggregate will polish to some friction value at about 4 million applications (actual traffic) and that this value will remain approximately constant after that period. This value after 4 million applications will vary (higher or lower) depending on the type and size of roadway contamination, etc. Therefore, 0 to 4 million applications should be within the range at which time the surface is polishing and 8 million should be near the lowest value expected.

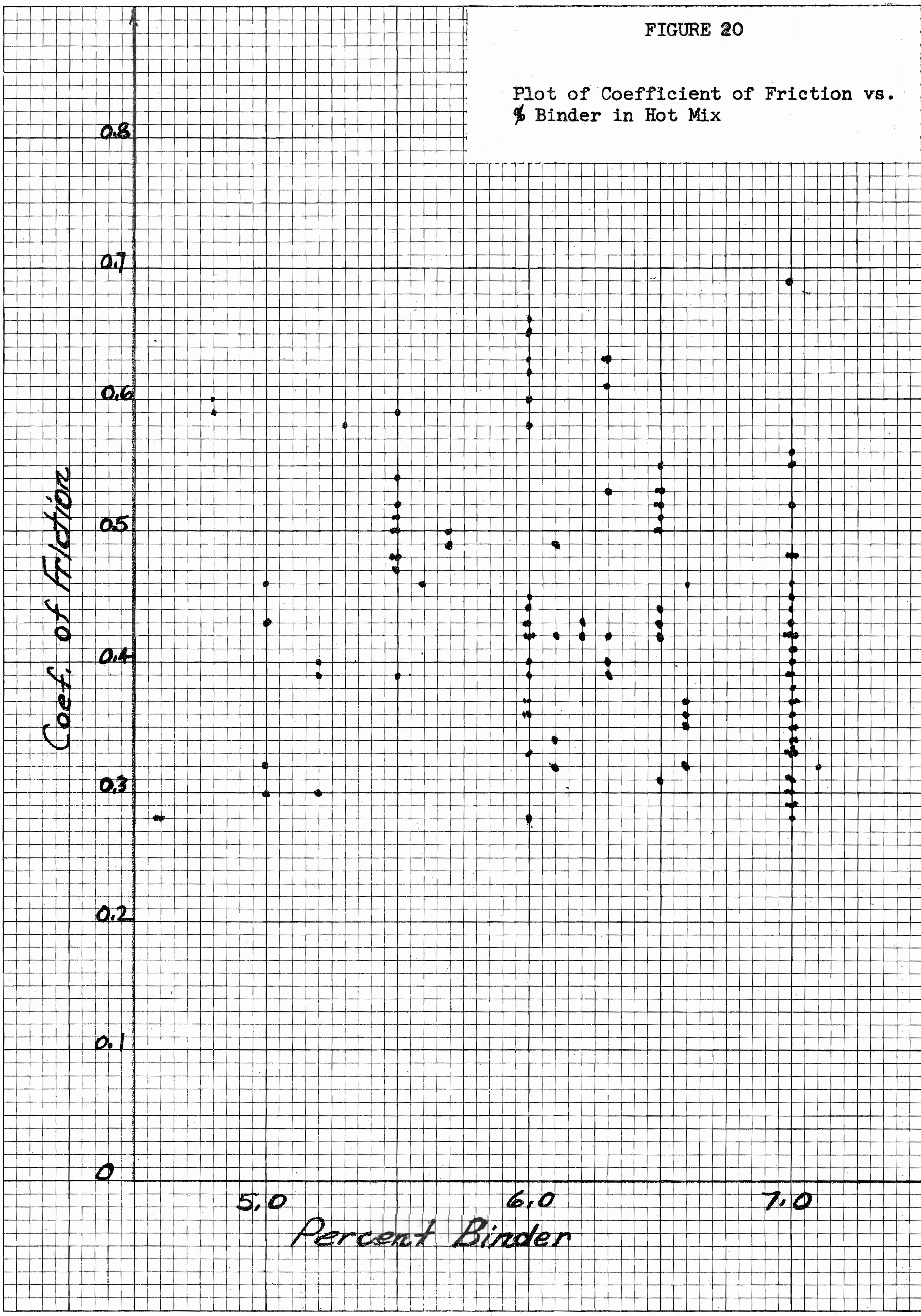
Figure 20 is the general plot of all HMAC pavements with Figure 21 though 26 related to specific coarse aggregate types. The results are disappointing However, there is one statement which can be made - higher asphalt contents do not appear to be hindering the friction values. There is probably an optimum asphalt content but this optimum is not readily apparent from these plots.

Surface Treatments

The traffic ranges selected for the surface treatments were (1) from 0 to 2 million applications and (2) 2 million or greater. When studying surface treatments and the traffic wear, there appears

FIGURE 20

Plot of Coefficient of Friction vs. % Binder in Hot Mix



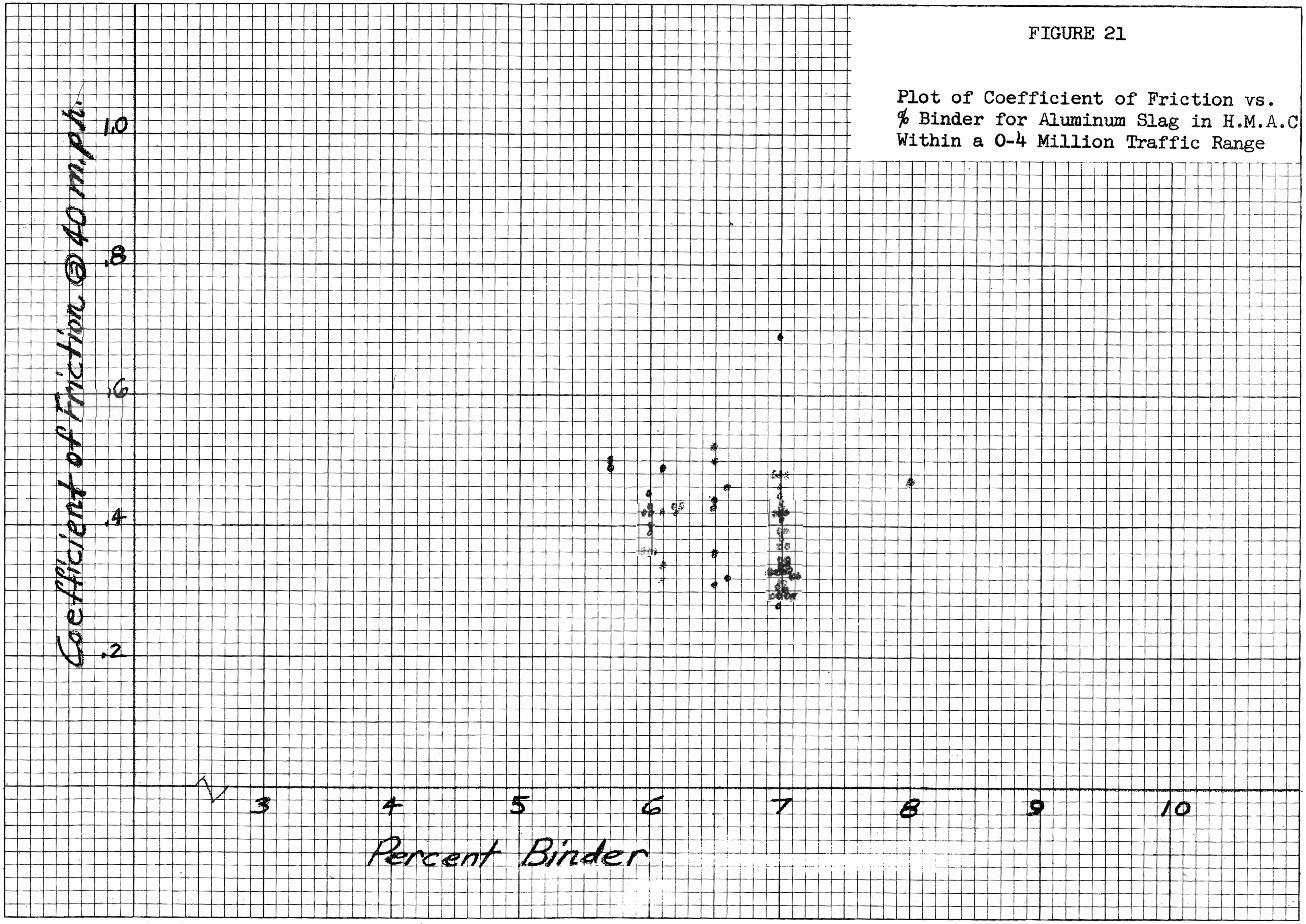


FIGURE 21

Plot of Coefficient of Friction vs. % Binder for Aluminum Slag in H.M.A.C Within a 0-4 Million Traffic Range

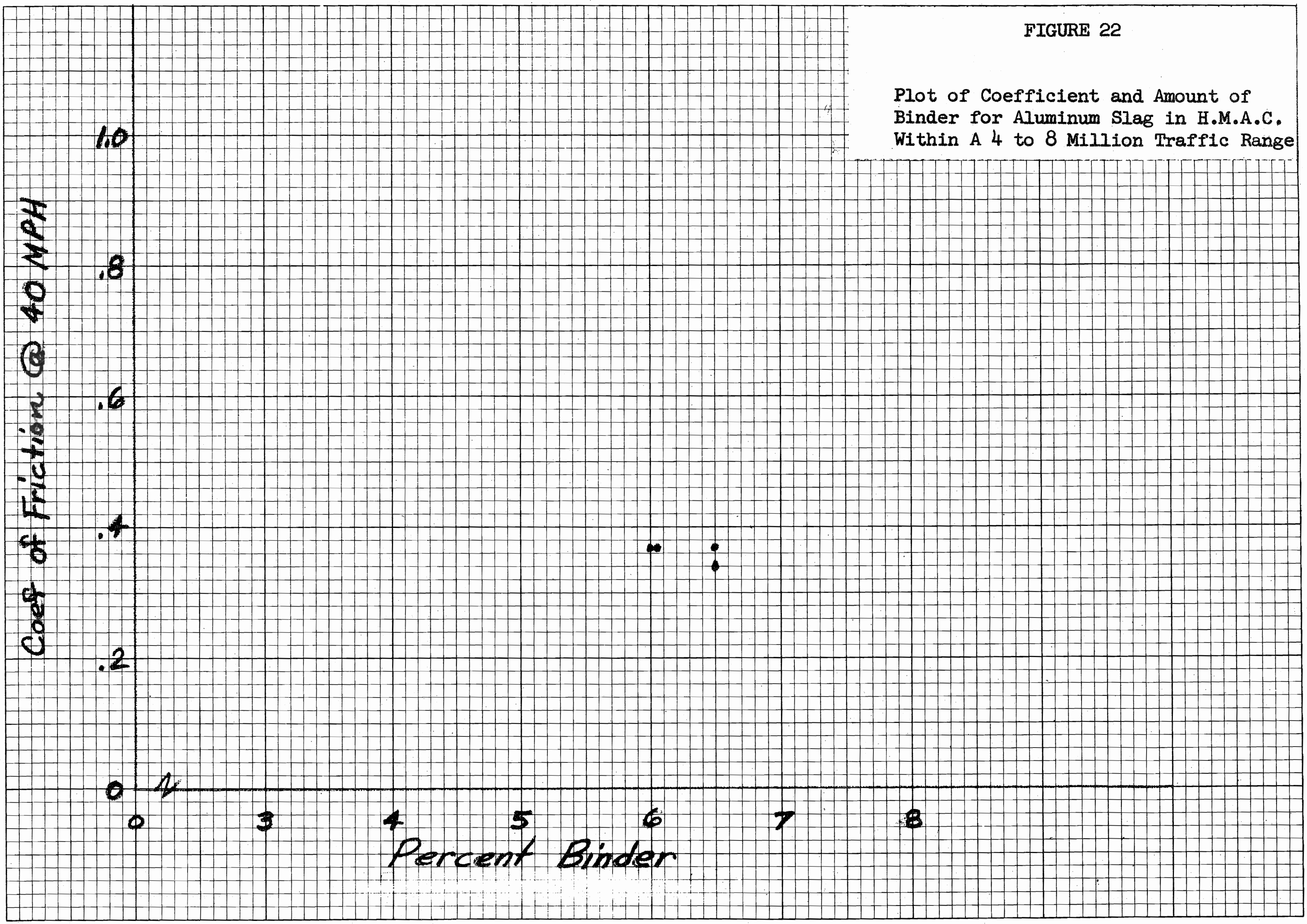
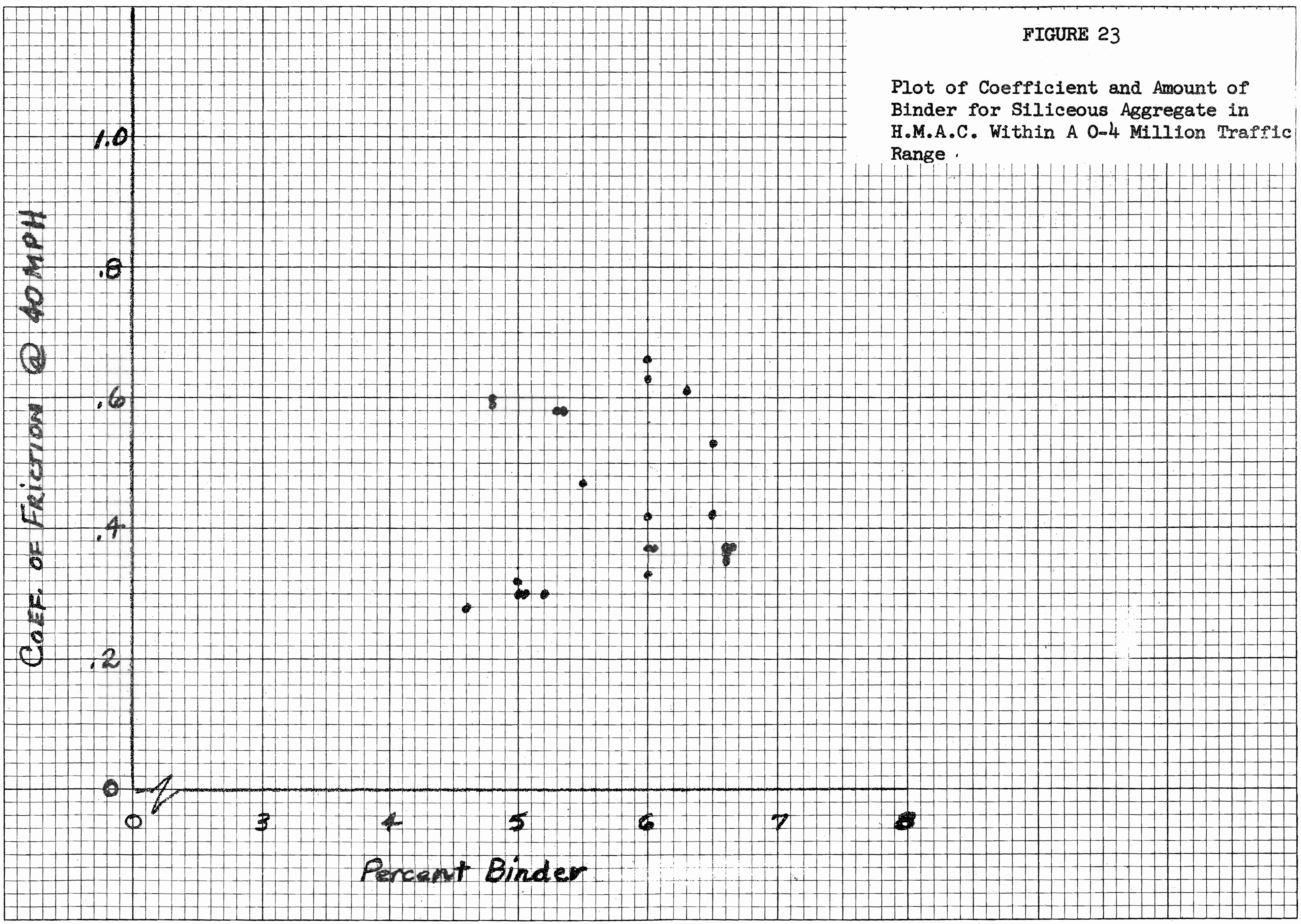


FIGURE 22

Plot of Coefficient and Amount of Binder for Aluminum Slag in H.M.A.C. Within A 4 to 8 Million Traffic Range

FIGURE 23

Plot of Coefficient and Amount of Binder for Siliceous Aggregate in H.M.A.C. Within A 0-4 Million Traffic Range



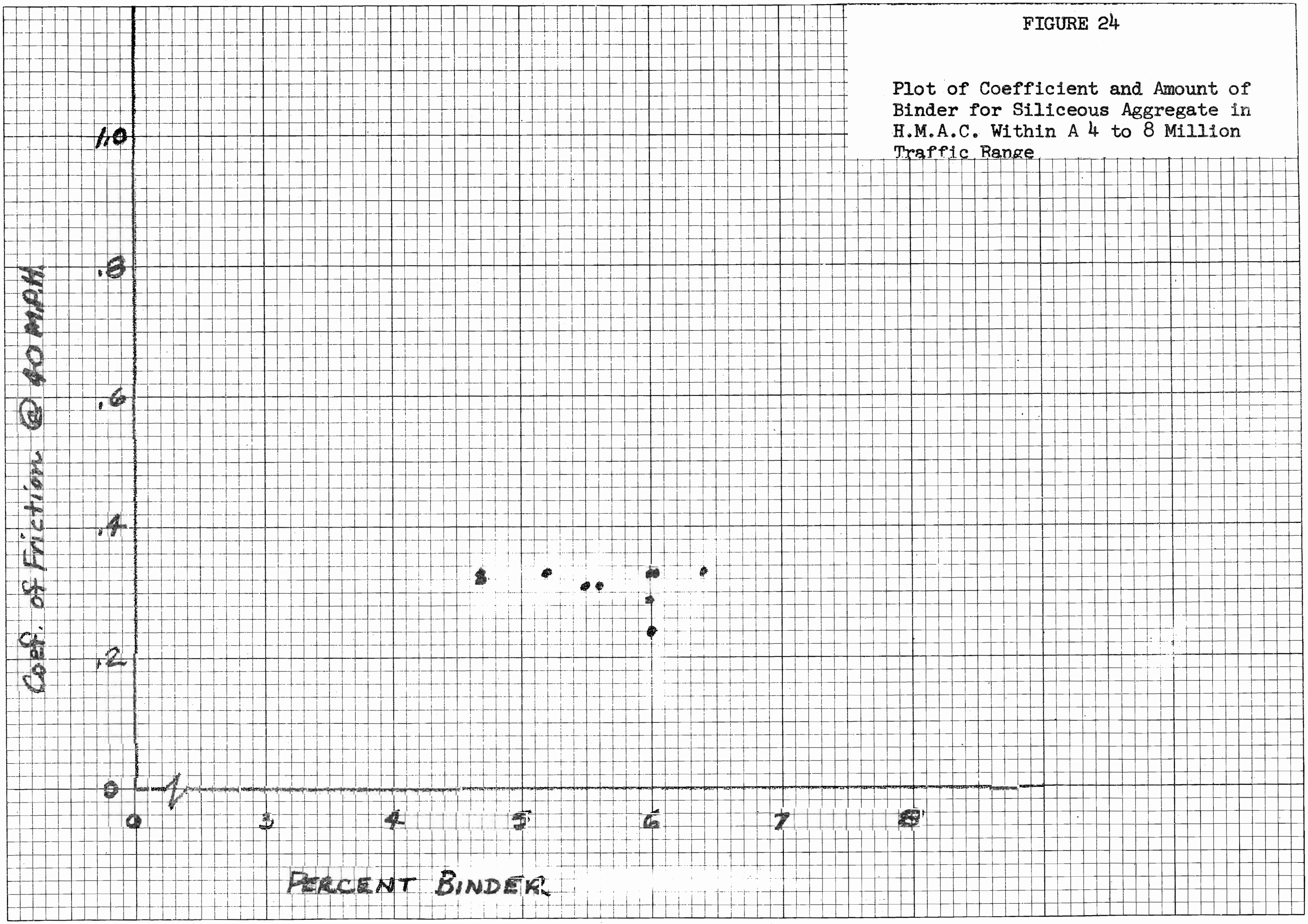


FIGURE 24

Plot of Coefficient and Amount of Binder for Siliceous Aggregate in H.M.A.C. Within A 4 to 8 Million Traffic Range

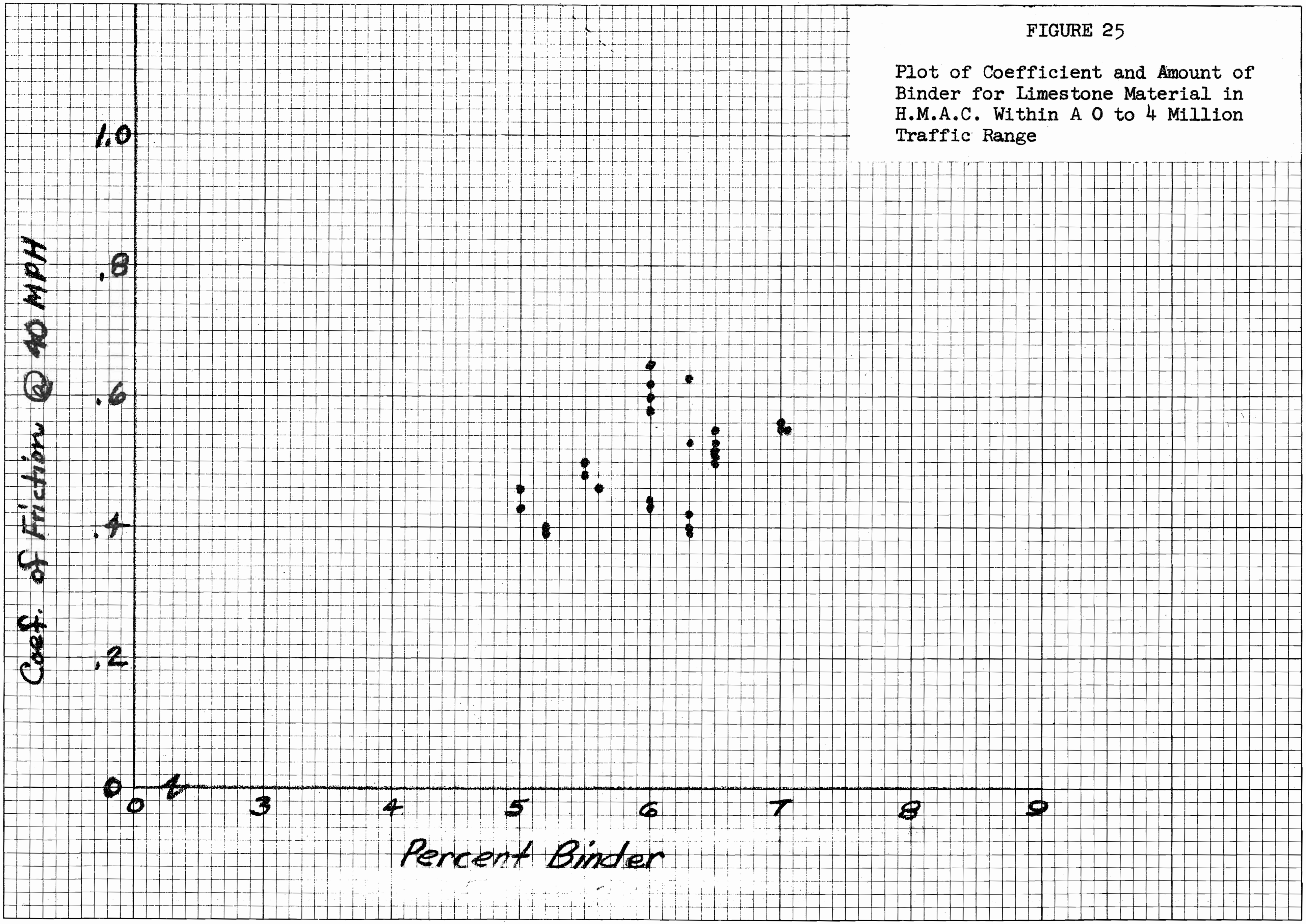


FIGURE 25

Plot of Coefficient and Amount of Binder for Limestone Material in H.M.A.C. Within A 0 to 4 Million Traffic Range

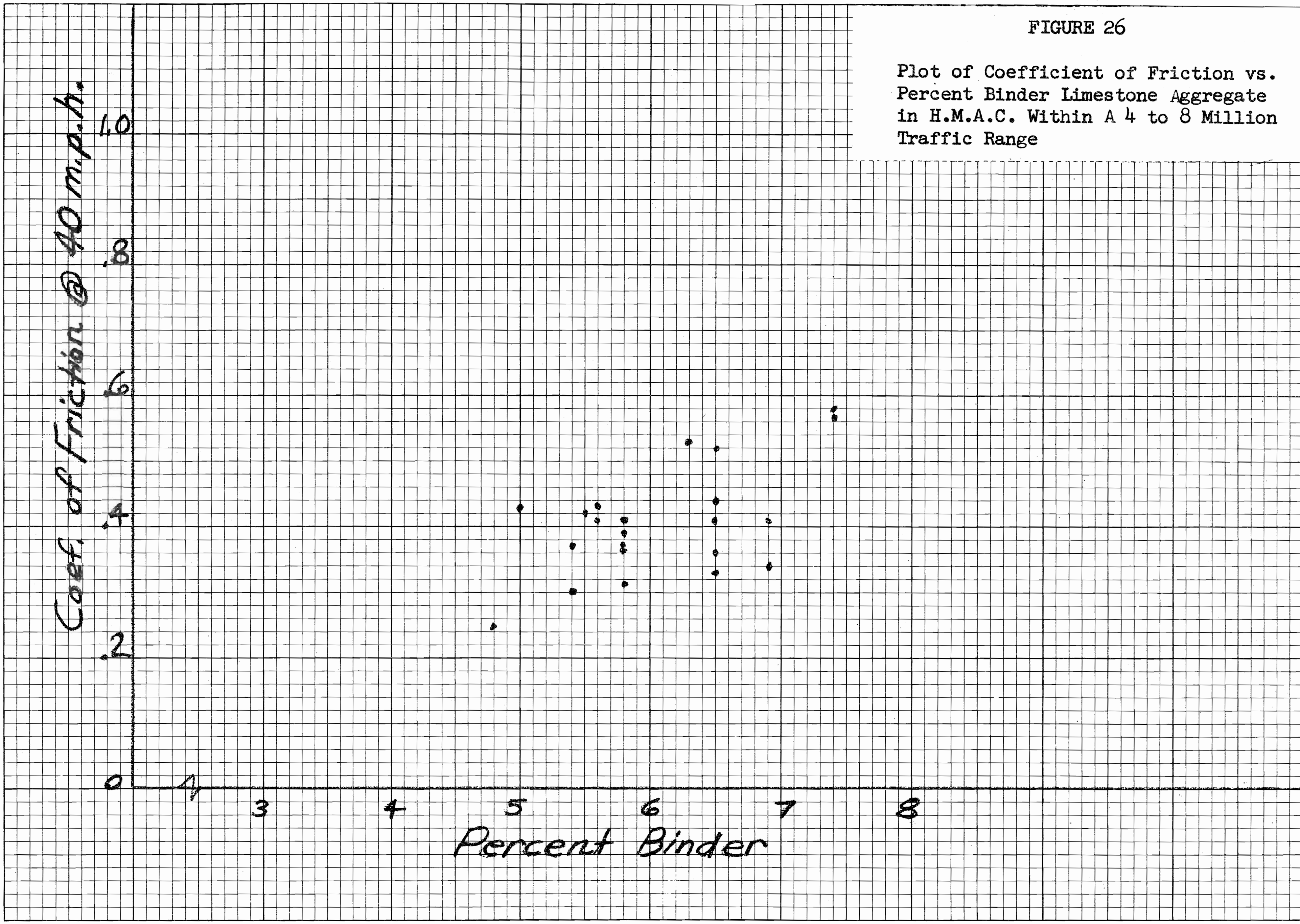


FIGURE 26

Plot of Coefficient of Friction vs. Percent Binder Limestone Aggregate in H.M.A.C. Within A 4 to 8 Million Traffic Range to be another variable which should be added - the amount of surface area which is composed of aggregate (left available to the vehicle tire). Since traffic is the principle cause of the destructive effort, the above traffic range was selected.

The general plot on Figure 27 would suggest an optimum amount of binder around 0.30 gal/s.y. and from 0.25 to 0.40 gal/s.y. suggested from Figures 28 and 29. It must be recalled that several pavements studied are seals in which the amount of binder has been varied to match the surface condition before sealing. Of course, the values coded by the Districts must be design or average values since the actual amount varies with land or distributor "shot". It is hoped that future analyses will reveal more positive results.

Slurry Seal

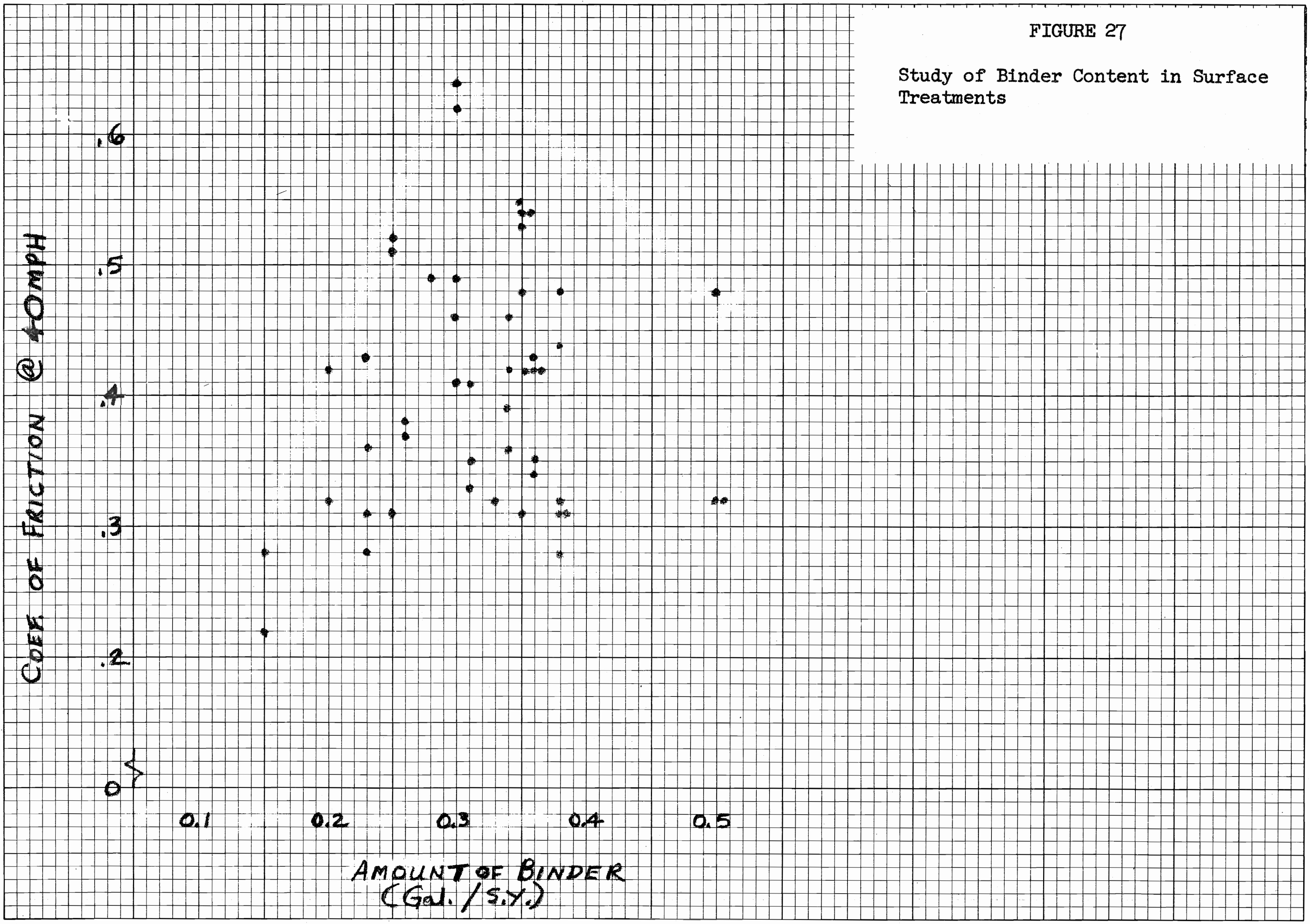
No definite trends show from the plot on Figure 30 due to the small amount of data.

Hot Mix Cold Laid

Again no definite trends are revealed because of lack of data points (See Figure 31).

FIGURE 27

Study of Binder Content in Surface Treatments



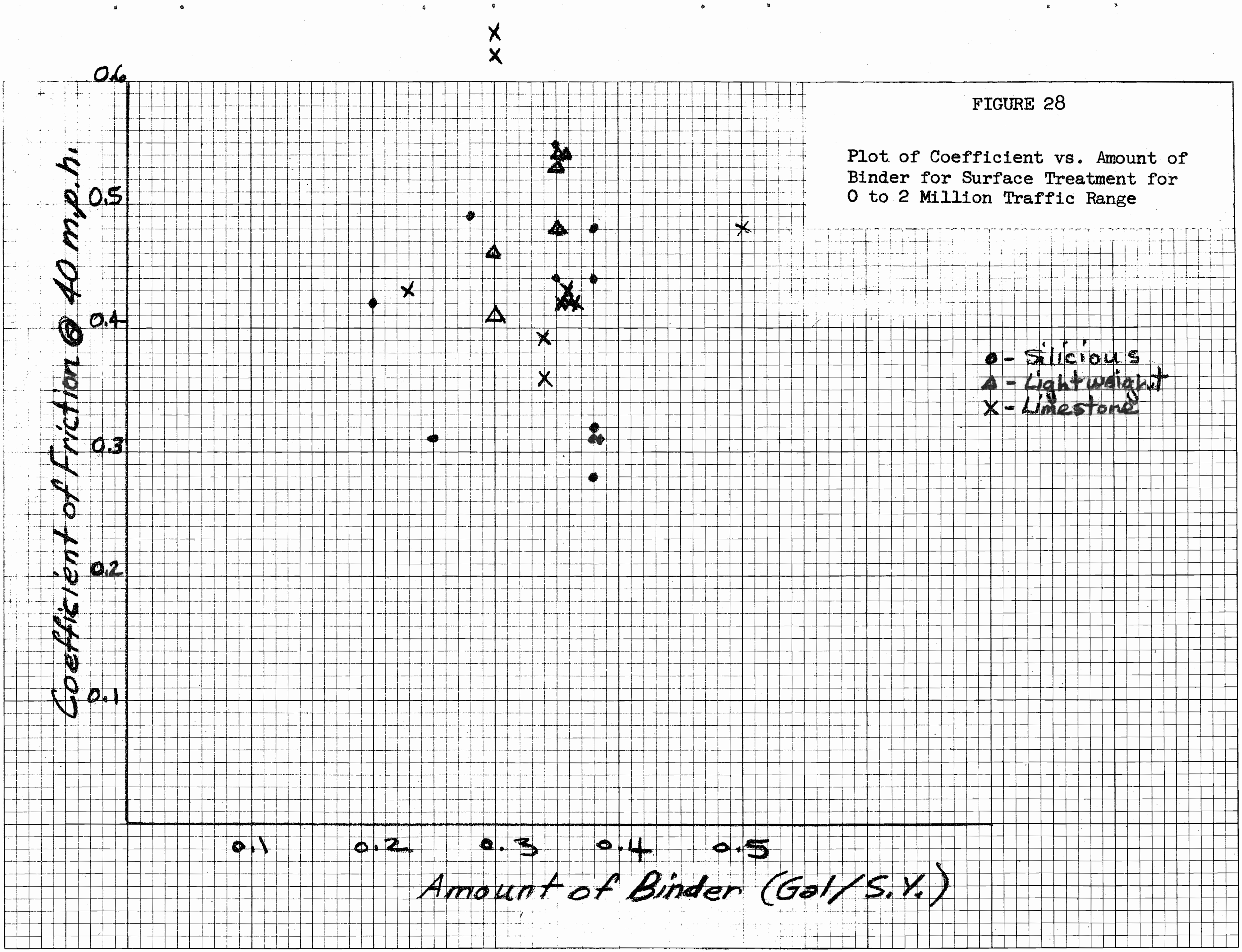


FIGURE 28

Plot of Coefficient vs. Amount of Binder for Surface Treatment for 0 to 2 Million Traffic Range

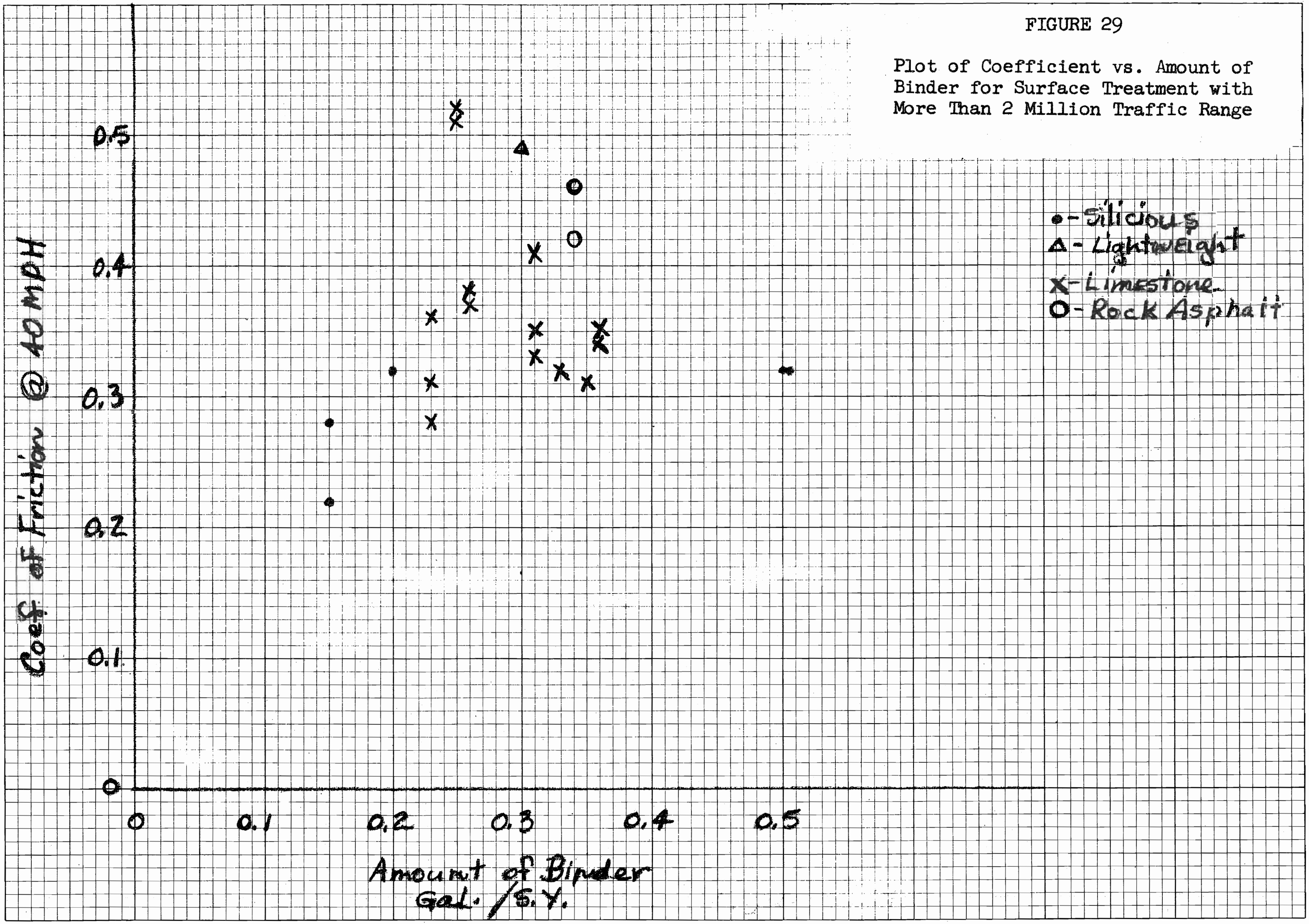


FIGURE 29

Plot of Coefficient vs. Amount of Binder for Surface Treatment with More Than 2 Million Traffic Range

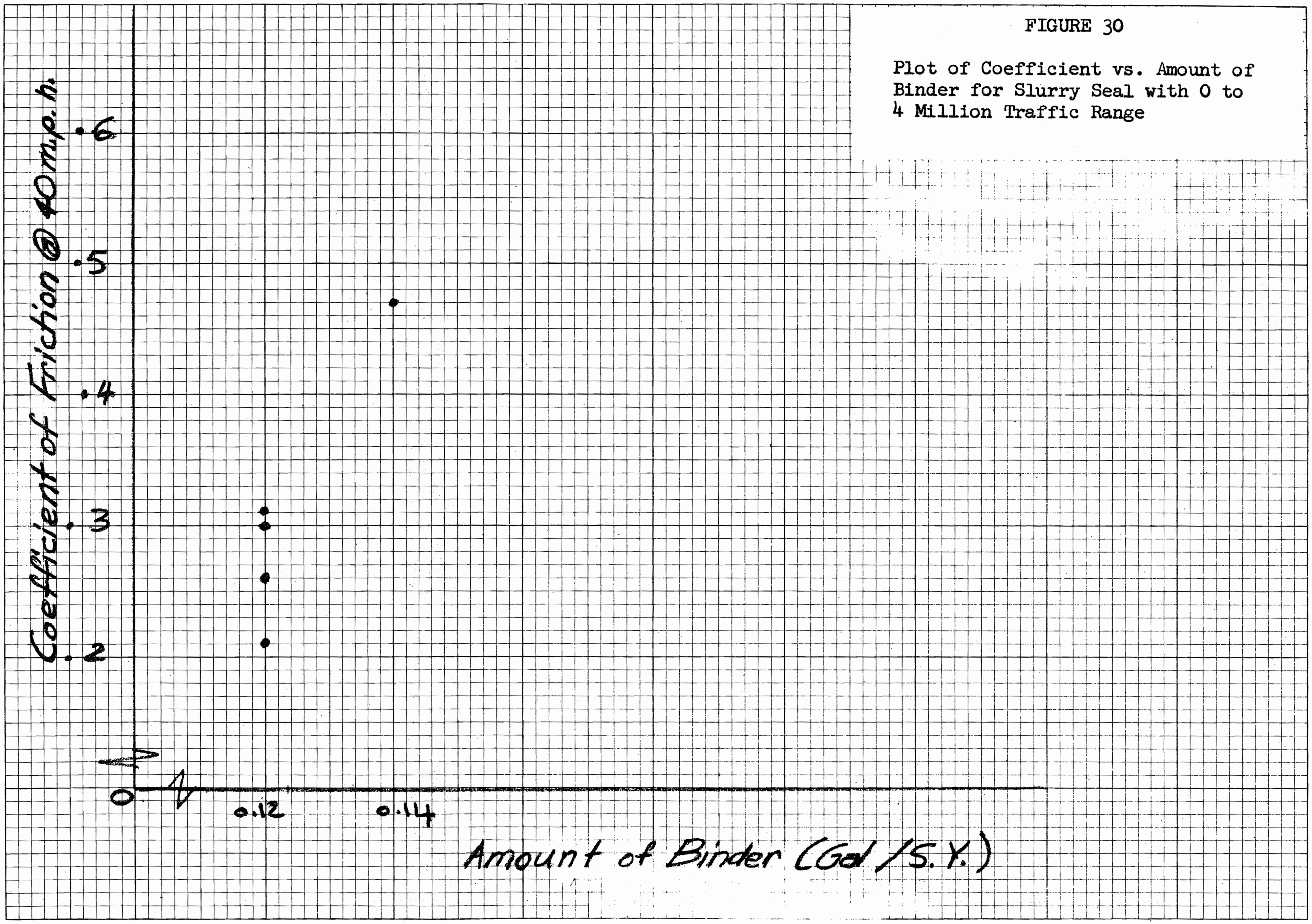
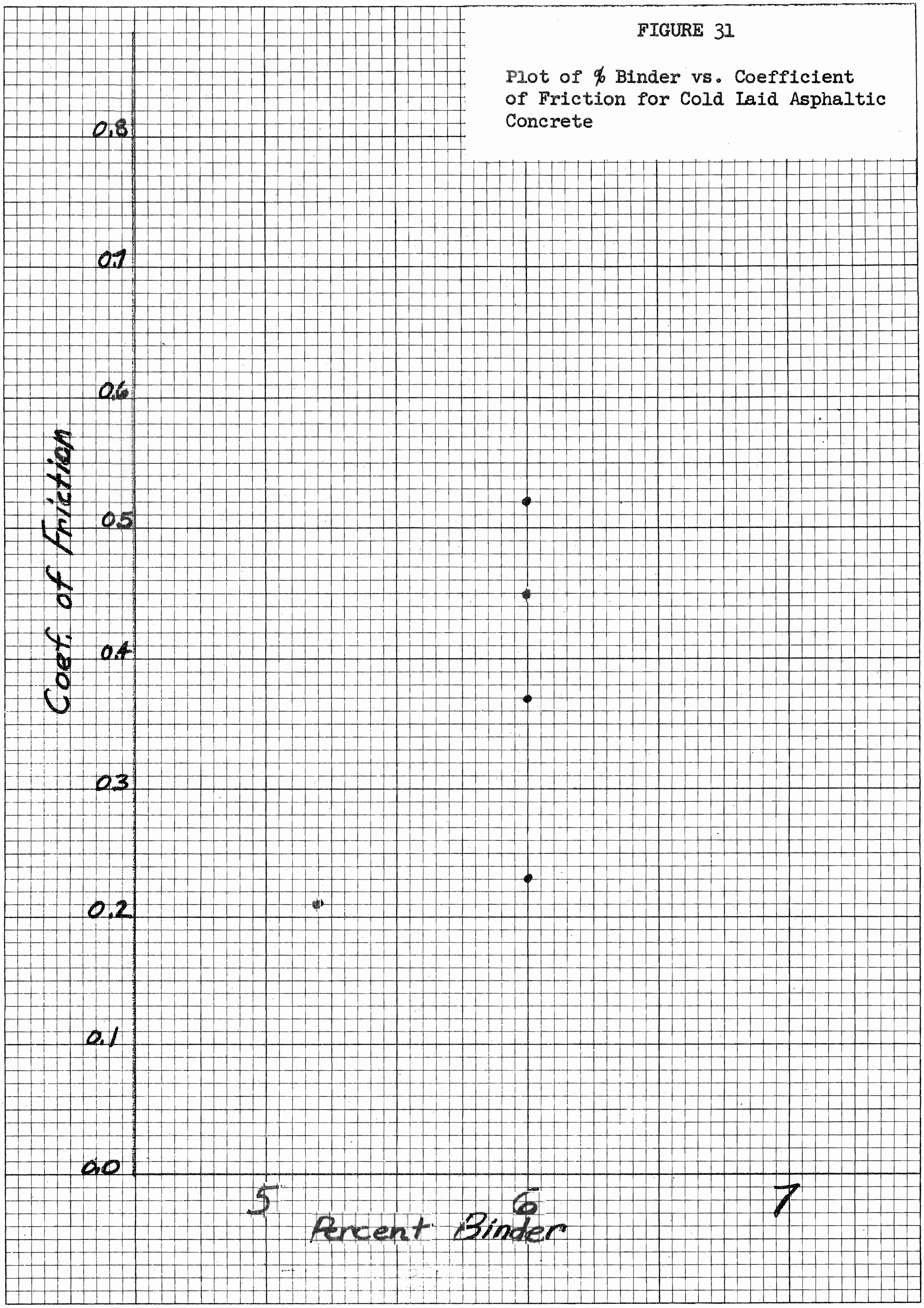


FIGURE 30

Plot of Coefficient vs. Amount of Binder for Slurry Seal with 0 to 4 Million Traffic Range

FIGURE 31

Plot of % Binder vs. Coefficient of Friction for Cold Laid Asphaltic Concrete



The Effect of Gradation

The study of gradation was similar to the study of the effect of the amount of binder. In several of the figures the amount of binder has been indicated near the data point in order to study the combination of gradation and amount of asphalt used.

Hot Mix Asphaltic Concrete

Figure 32 reveals the general plot for the HMAC sections studied. Figures 33 through 37 concern the various material types and traffic ranges.

Surface Treatment

Figure 38 shows the general plot for the Surface Treatment sections studied and Figures 39 through 41 indicate gradation and binder contents for the material types and traffic ranges.

FIGURE 32

Coefficient of Friction vs. Gradation for Hot Mix

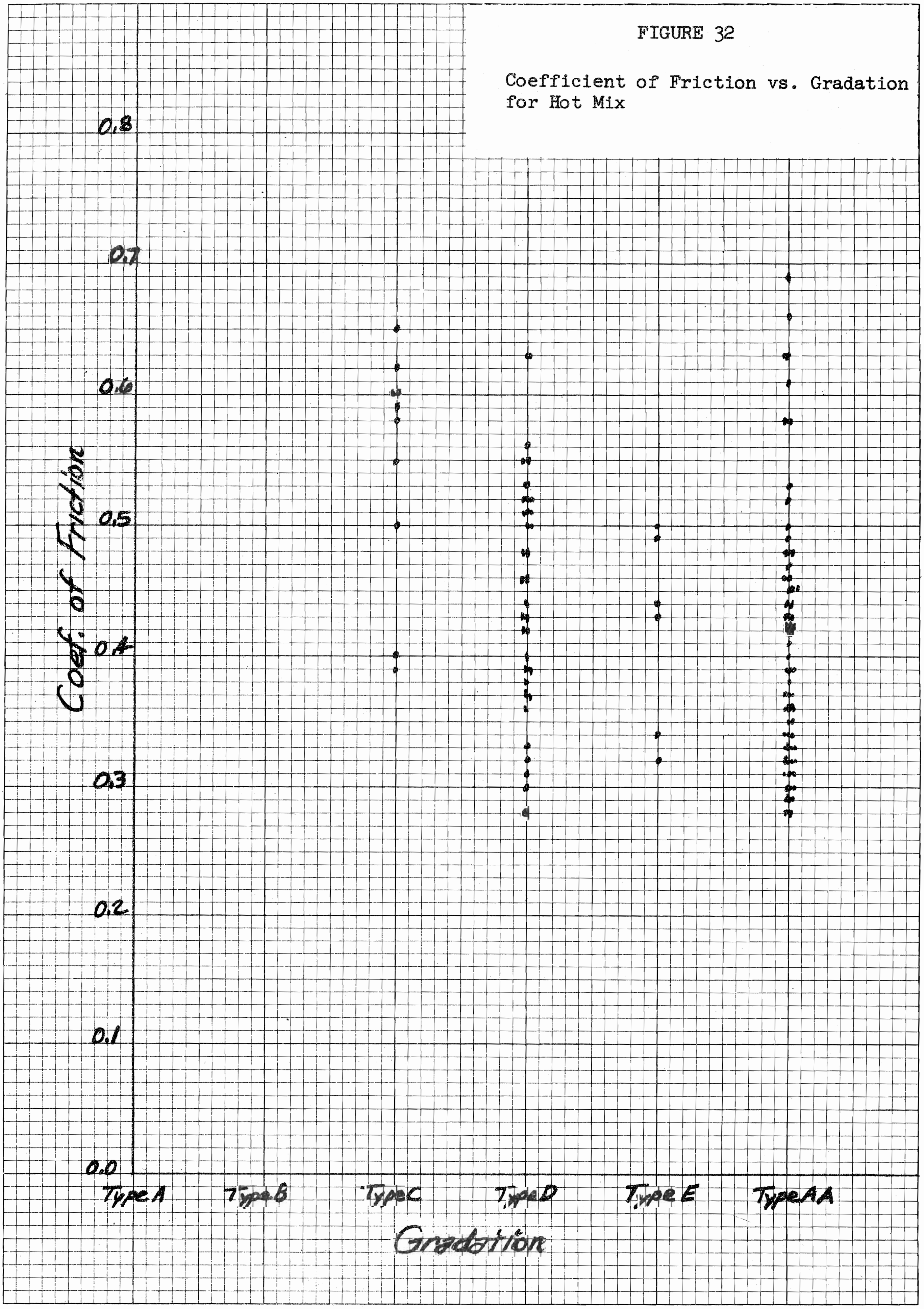


FIGURE 33

Coefficient of Friction vs. Gradation for Limestone C. Aggregate Used In H.M.A.C. for 0 to 4 Million Traffic Range

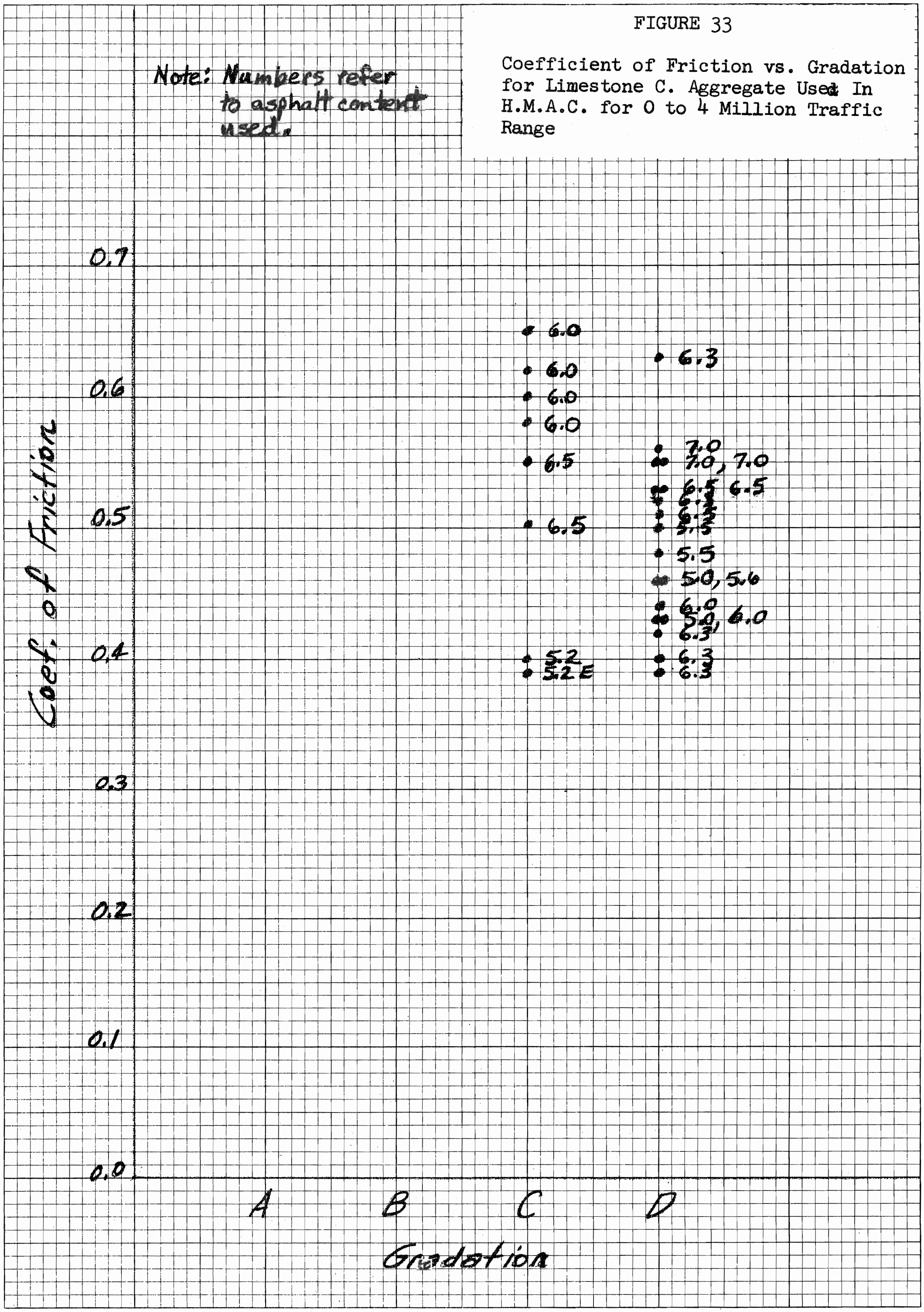


FIGURE 34

Coefficient of Friction vs. Gradation for Limestone C. Aggregate Used In H.M.A.C. for 4 to 8 Million Traffic Range

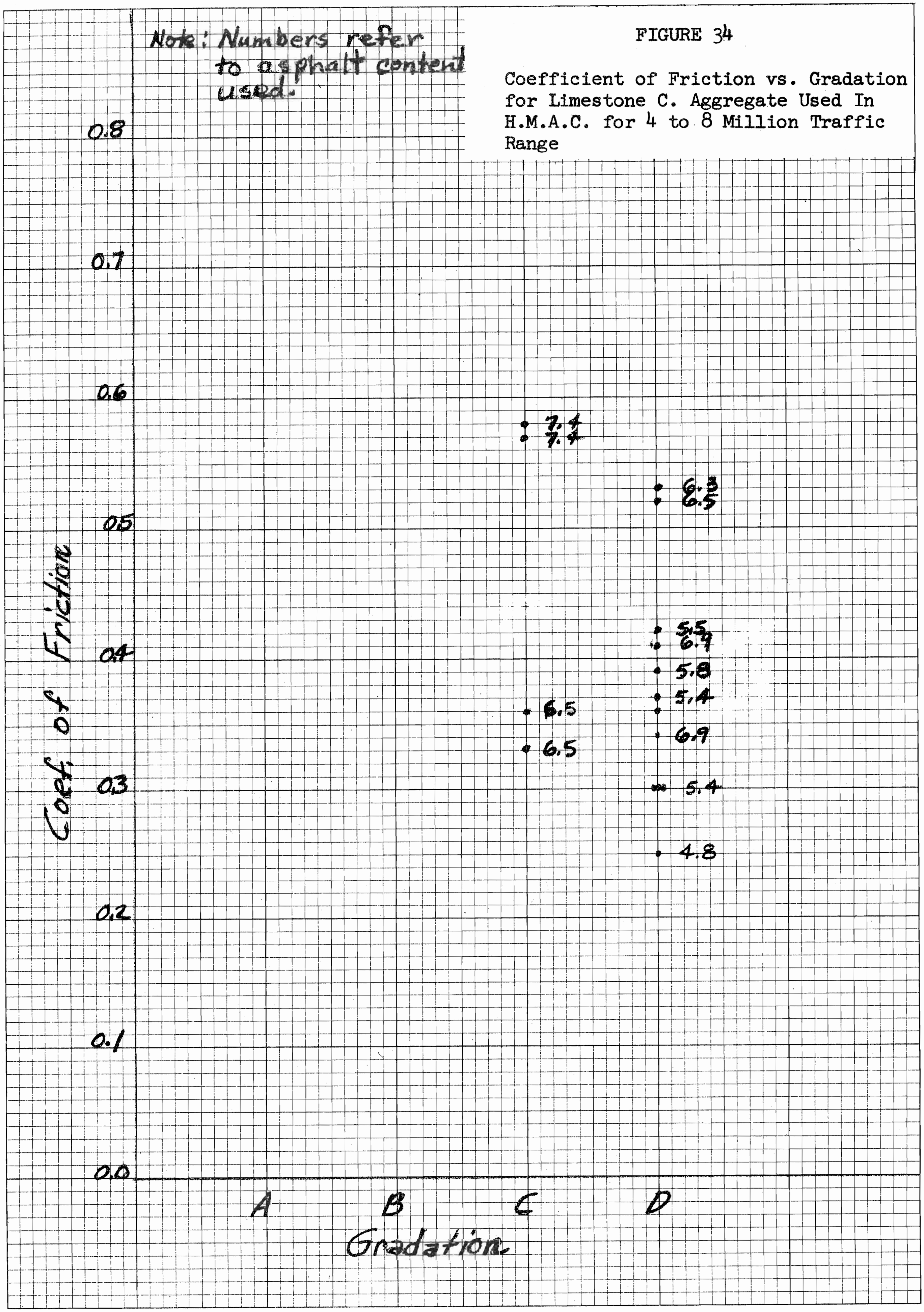


FIGURE 35

Coefficient vs. Gradation for Siliceous Coarse Aggregate Used In Hot Mix for 0 to 4 Million Traffic Range

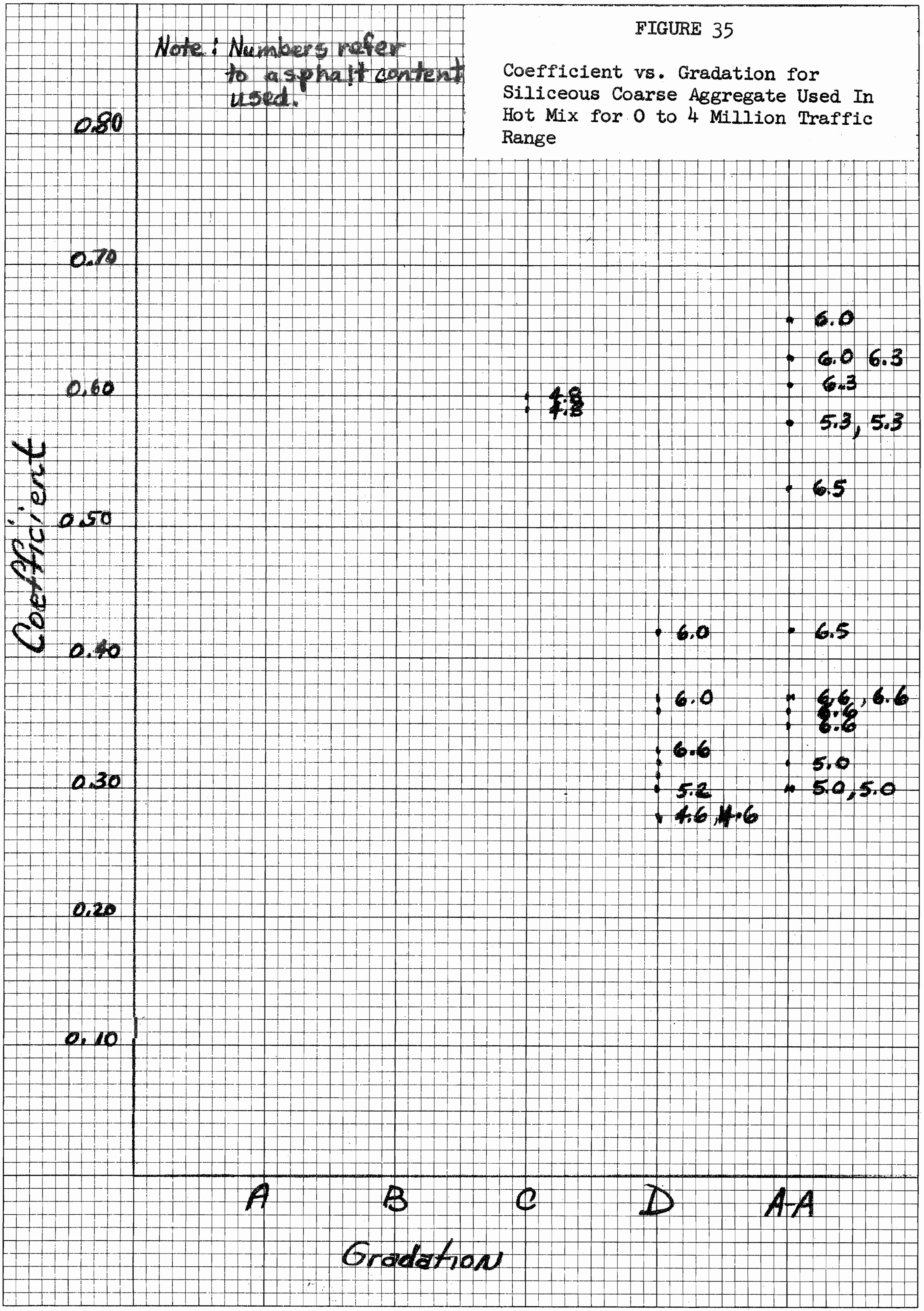


FIGURE 36

Coefficient of Frictions vs. Gradation for Siliceous Aggregate Used in H.M.A.C. for 4 to 8 Million Traffic Range

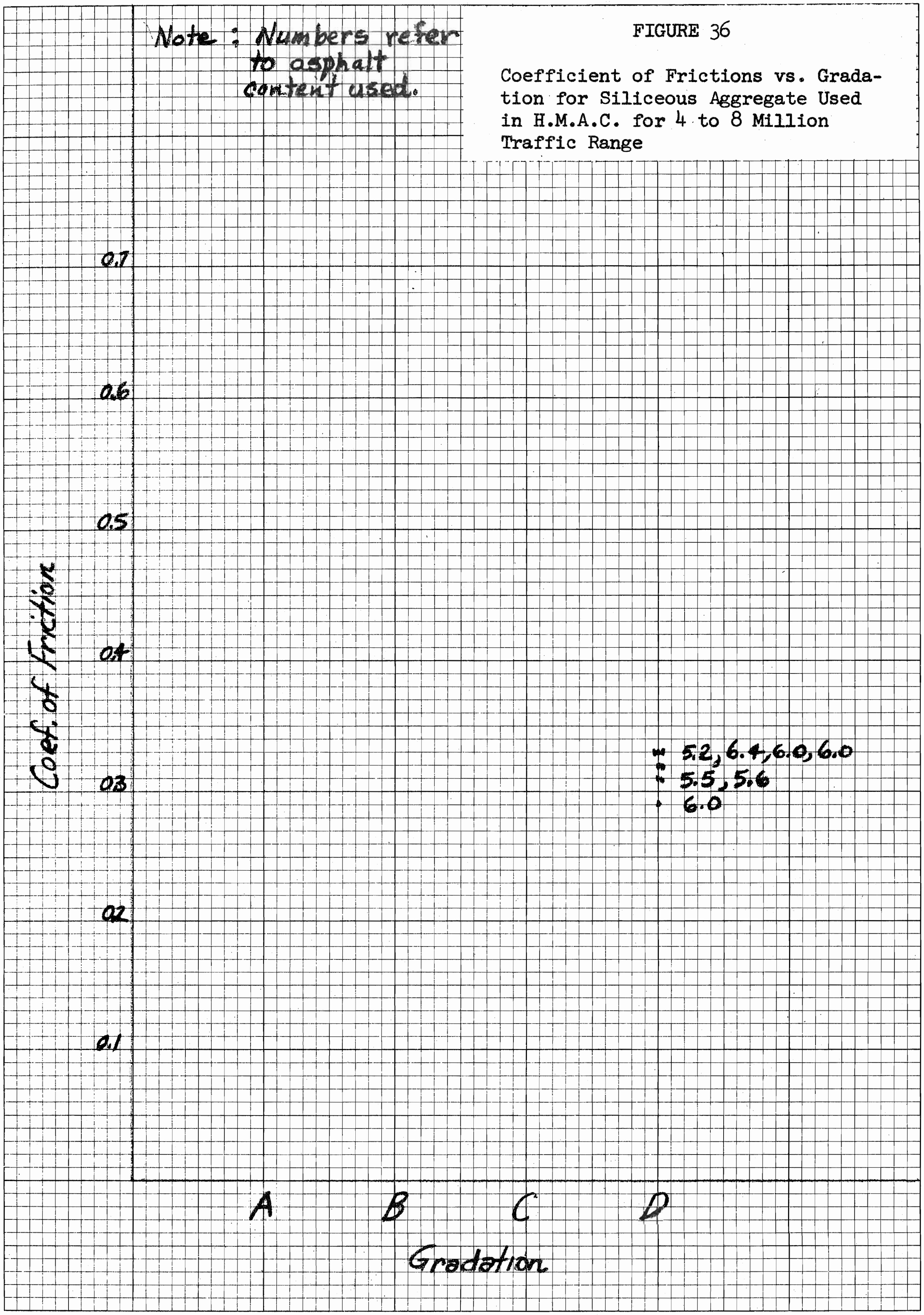
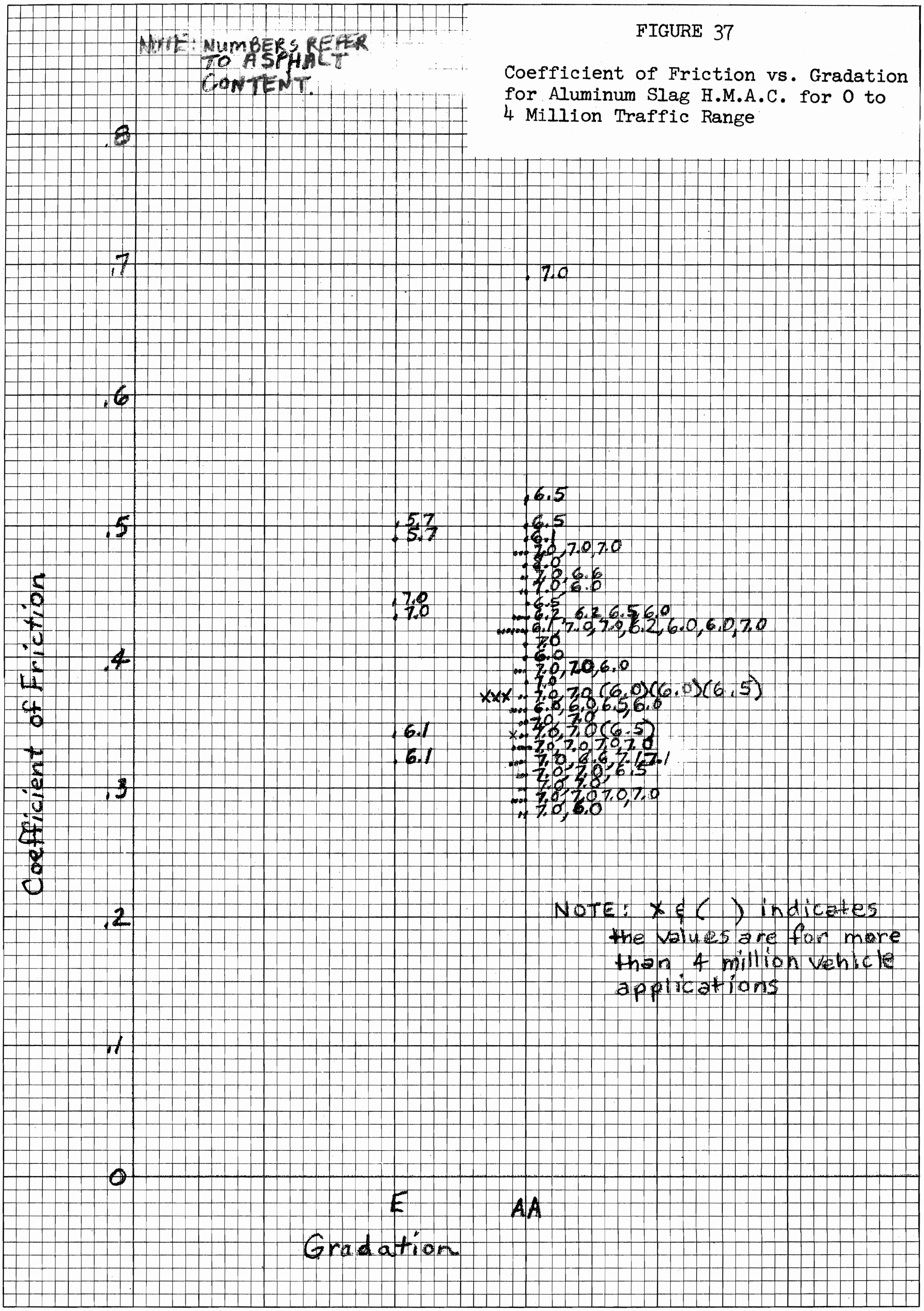


FIGURE 37

Coefficient of Friction vs. Gradation for Aluminum Slag H.M.A.C. for 0 to 4 Million Traffic Range



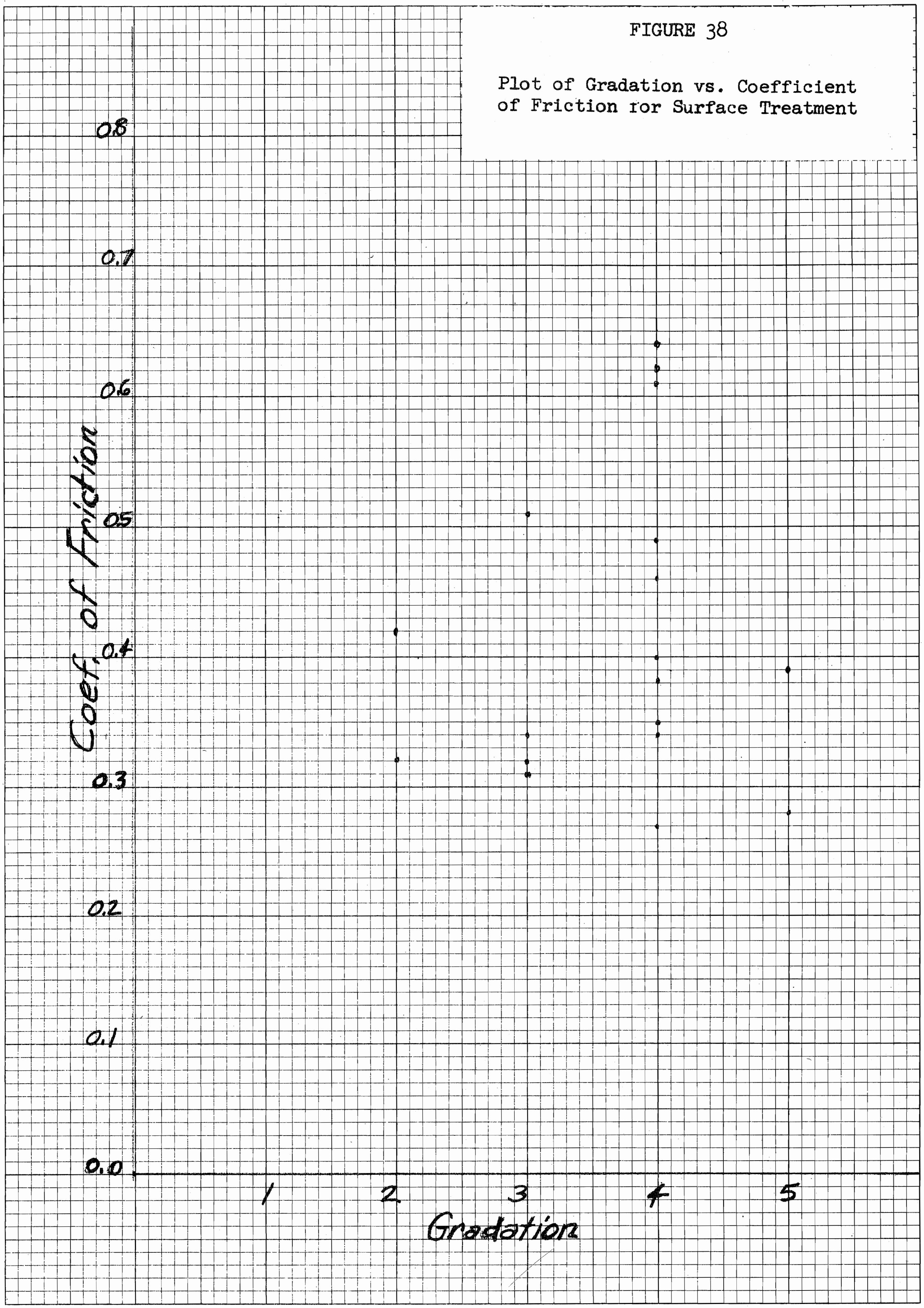


FIGURE 38
Plot of Gradation vs. Coefficient of Friction for Surface Treatment
Coef. of Friction
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
Gradation

FIGURE 39

Coefficient vs. Gradation for Siliceous Coarse Aggregate for Surface Treatment for 0 - 4 Million Traffic Range

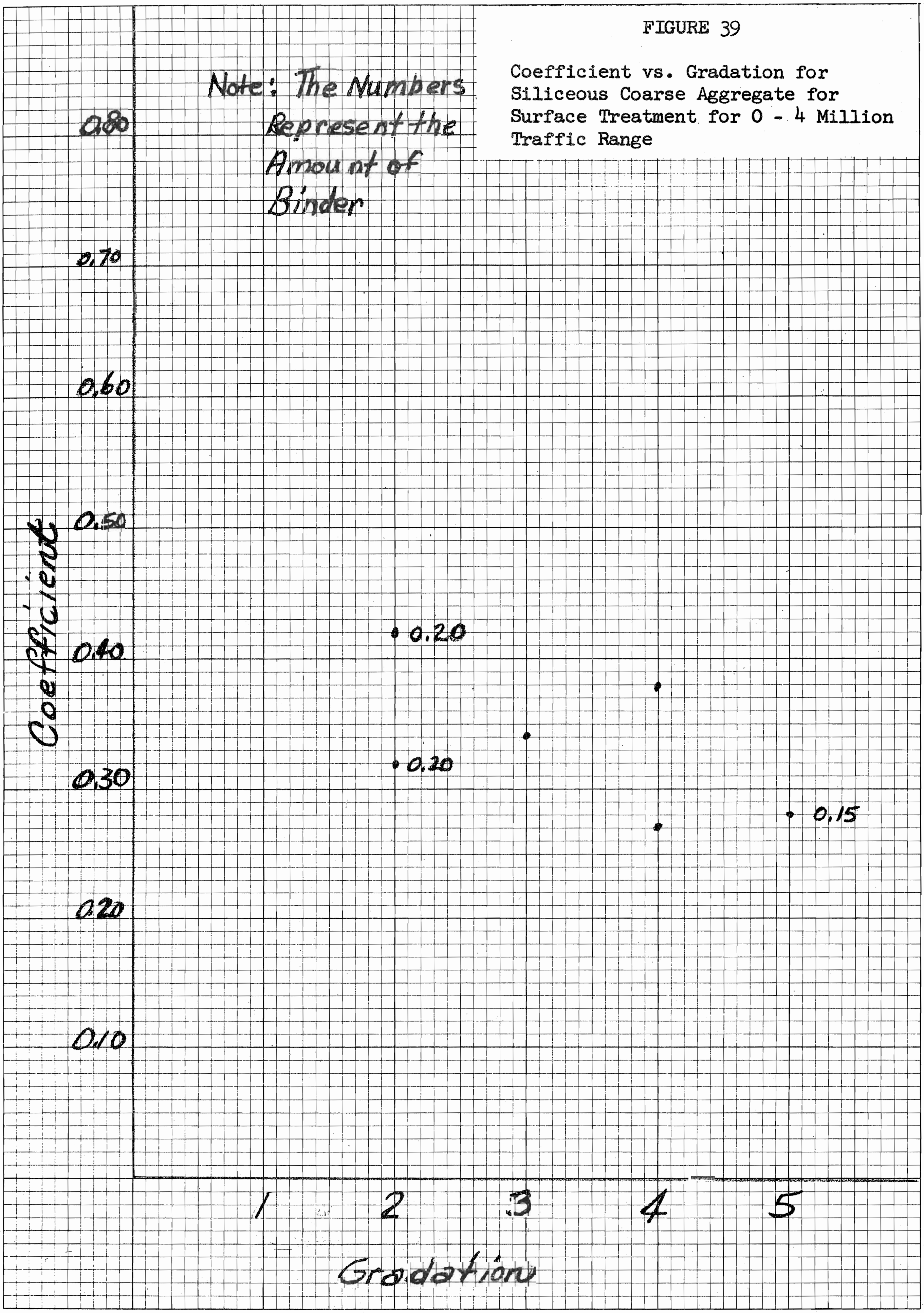


FIGURE 40

Coefficient of Friction vs. Gradation for Lightweight Coarse Aggregate for Surface Treatment for 0 to 4 Million Traffic Range

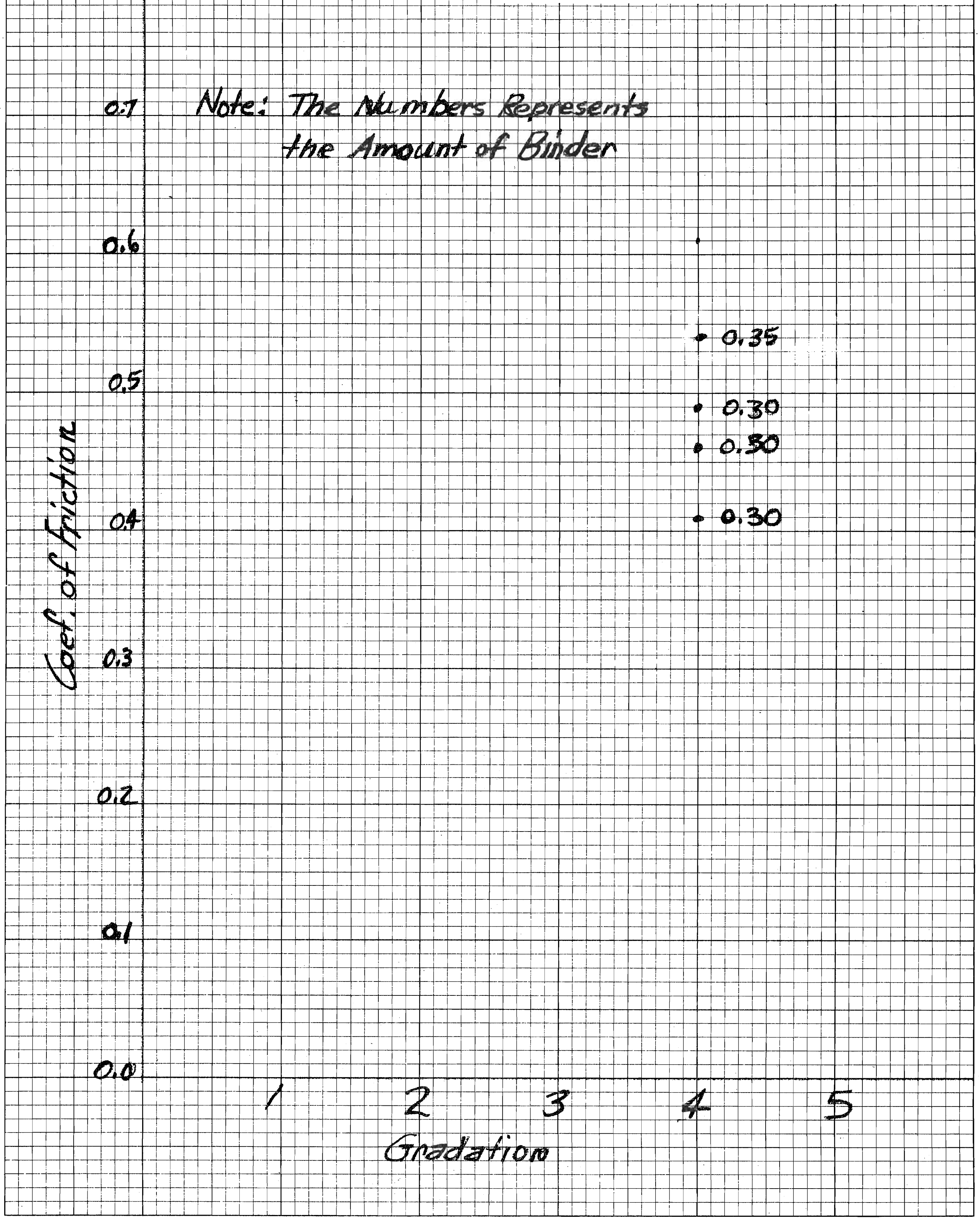


FIGURE 41

Coefficient of Friction vs. Gradation for Limestone Coarse Aggregate Used in Surface Treatment for 0 to 4 Million Traffic Range