COMPACTION OF ASPHALTIC CONCRETE PAVEMENT WITH HIGH INTENSITY PNEUMATIC ROLLER
PART II - DENSIFICATION DUE TO TRAFFIC

By

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SYNOPSIS

The data contained in this report are the follow up on the experimental section constructed in 1961 to study the effect of high intensity pneumatic rollers on the density of asphaltic concrete pavement using different compactive efforts and number of passes. Results of this preliminary study were reported in Louisiana Department of Highways Research Report No. 10. This report is chiefly concerned with the effect of traffic on the densification and rutting of these experimental sections.

These periodic surveys indicated (1) that most of the increase in compaction occurs during the first six months' traffic after which time this rate decreases; (2) that 85 psi section requires the least number of coverages for optimum conditions and has the least magnitude of rutting for given number of passes after three years' traffic; (3) furthermore, that majority of the sections have reached 100% of the 75-blow plant and laboratory design density.

COMPACTION OF ASPHALTIC CONCRETE PAVEMENT WITH HIGH INTENSITY PNEUMATIC ROLLER PART II - DENSIFICATION DUE TO TRAFFIC

INTRODUCTION

In the early part of 1961 a research project was undertaken by the Louisiana Department of Highways in cooperation with the Bureau of Public Roads to study the effect of high intensity pneumatic rollers on the density of asphaltic concrete pavement using different compactive efforts and number of passes. This had resulted from a traffic survey conducted during the summer of 1959 which had indicated axle loads of up to 24,000 lb or wheel loads of 6,000 lb and tire inflation pressure of up to 115 psi at service temperatures. This results in contact pressures of 120 psi for maximum conditions and 75 to 85 psi for average conventional loaded truck conditions. The pneumatic tired rollers hitherto in use in Louisiana with 2000 lb wheel load and 55 psi inflation pressure exert anywhere from 37 to 55 psi of contact pressure, a range well below that imposed by the present day heavy truck traffic. In order to equalize the rolling pressures with those being obtained under truck traffic, this study was conducted with a view to eliminate or at least minimize rutting of asphaltic concrete surfacing.

SCOPE

The investigation was conducted on 61 test sections of hot-mix hot-laid asphaltic concrete pavement consisting of 1 1/2 inches of wearing course overlaying a binder course of 2 1/2 inch thickness on flexible and rigid base. These sections were divided into the following:

(1) Fourteen sections on wearing course overlaying a binder course on flexible base.

(2) Twenty-two sections on wearing course overlaying a binder course on rigid base.

(3) Ten sections of binder course on flexible base.

(4) Fifteen sections of binder course on rigid base.

Preliminary investigation on the above sections was concluded in January, 1962 on State Project 13-10-24, Robert-Covington Highway on US 190, having an annual average daily traffic of 2800, 22% of this being truck traffic. For this section of the highway, the total number of axles per day in the 10 to 20 kip group is 395. Results of this preliminary field investigation including details of construction procedure, equipment, etc., are all explained in Louisiana Department of Highways Research Report No. 10.[1]

This report is primarily concerned with the evaluation of roadway density as affected by traffic over a period of time subsequent to construction. These periodic surveys which were made 6, 15, 24, and 36 months after the initial construction period included (1) cutting cores for density determination, two from each wheel path and one from the centerline, (2) measurement of longitudinal grooves and (3) visual observation of surface condition.

A summary of roadway compaction results and wheel path rutting for wearing course mix is presented in Tables I and II. Graphical relationship of these are indicated in Figures 1 through 11. The binder course results are likewise presented in Tables III and IV with the corresponding graphical relationships in Figures 12 through 15. Table V and Figures 16 and 17 represent data on laboratory and plant compaction correlation. All these tables and figures appear in the Appendix.

In the following discussion, per cent compaction refers to roadway specific gravity expressed as per cent of mechanically compacted plant specific gravity.

DISCUSSION OF TEST RESULTS

Wearing Course on Flexible Base

Figures 1 and 2 show number of passes, per cent compaction - compactive effort relationships for the wearing course mixture on surface treatment and flexible base using 75 and 85 psi contact pressures, respectively.

(1) Verdi Adam, et al., Compaction of Asphaltic Concrete Pavement With High Intensity Pneumatic Rollers - Part I, Research Report No. 10, July, 1963

Average results for these sections are shown in Table I. It can be seen from these figures that major portion of the increase in compaction has occurred during the first 6 months of traffic. Furthermore, the optimum condition of 15 passes at 75 psi contact pressure show the least increase in compaction during the six-month period than corresponding increase at other compactive efforts for the same period. Thirty-six month curve indicates a slight decrease in compaction from the original at the optimum. Although compaction using 50-blow Marshall density show higher values than 75-blow density, none have however reached 100% of the plant density.

The magnitude of wheel path rutting has not been excessive after three years of traffic. The least ruts were observed on section with 9 passes (4. 3 mm or . 17 in) and the largest for 19 passes (7. 4 mm or . 29 in). For the optimum condition the average measurement was 6. 2 mm or . 24 inches.

Sections compacted at 85 psi contact pressure had indicated 9 passes to be the optimum during preliminary investigation (Figure 2). Six months of traffic show the least increase in compaction for this optimum condition. For this section, contrary to expectations, wheel path rutting is the greatest with 19 passes showing the least.

Wearing Course on Rigid Base

The relationship between number of passes and per cent compaction for wearing course mixture on rigid concrete base at different magnitudes of the compactive effort is illustrated in Figures 3 through 5. For this condition, concurrent effect on the densification due to reduction in asphalt content is also shown. At 6. 0% asphalt content and 75 psi contact pressure (Figure 3), the position of the peak during the preliminary investigation could not be determined as also after six month which indicated straight horizontal line relationship. However, on the basis of three-year density and rut measurement, 19 passes seem to be the optimum for this field compactive effort. Reduction in asphalt content by . 2% had induced 98. 2 and 97. 8% of 50 - and 75-blow of plant compaction respectively using 17 passes of the pneumatic roller. Once again, most of the increase in compaction has occurred during the first six months of traffic.

The optimum compaction at 85 psi contact pressure was at 9 passes for both the asphalt contents. Likewise, the per cent increase in compaction and the corresponding wheel path rutting due to six months' and 3 years' traffic is also the least for these optimum conditions (Figure 4).

For this study the control sections were represented by 55 psi contact pressure for which the relationships are indicated in Figure 5. For either asphalt content 19 passes seems to be the optimum. The wheel path rutting for these sections is also the least.

All the above relationships when expressed as function of time gave Figures 6, 7, 8, and 9. The ordinates are represented by differential increase in per cent compaction from the original. The data on the figures warrant the following comments:

(1) The greatest increase in compaction occurs during the first few months after construction after which period this rate decreases with a tendency to taper off.

(2) Fluctuation in per cent compaction is evidenced by way of compaction and decompaction. Such a condition could be associated with displacement of the pavement mat due to heavy truck traffic.

Relationship between contact pressure-per cent compaction-longitudinal grooves for given number of passes is represented by bar charts in Figures 9 and 10. Using 5.8% asphalt, the rutting decreases with increasing contact pressure. Likewise, the per cent increase in compaction is also the least at 85 psi contact pressure. This condition is also evident for the section with 6.0% asphalt content.

Binder Course Relationships

When the effect of traffic on the densification of binder course sections was investigated, Figures 12 through 15 were obtained. Density survey after 15 months was discontinued due to considerable fluctuation in these values. Data on these figures warrant the following comments:

(1) Sections showing optimum condition during construction using 85 psi contact pressure (9 passes on flexible base and 11 on rigid) indicate decompaction after 6 months of traffic after which period compaction is once again resumed. However, the numerical value of this subsequent compaction has not as yet reached the original.

(2) The 75 psi optimum section with 13 passes on flexible base and 15 passes on rigid base show a slight amount of increase in compaction after 15 months of traffic. Furthermore, none of the sections indicate presence of any decompaction as was indicated at 85 psi pressure.

(3) All the sections on rigid base have either equaled or exceeded the 100% of the 75-blow plant density. Corresponding sections on flexible base have not reached this condition with the exception of the optimum section at 75 psi pressure.

FIELD AND LABORATORY DENSITY CORRELATION

Table V shows comparison of different methods of laboratory compaction and optimum field compaction results for sections subjected to different compactive efforts. Field results were obtained from Figures 1 through 5 for wearing course and from 12 through 15 for binder course sections and further converted to density values. Design density results were likewise obtained from Figures 16 and 17.

Data in the table indicate (1) that there is considerable variation in Marshall densities for plant and laboratory compacted specimens using the two compactive efforts; (2) that with the exception of 75 psi wearing course sections, all have either equaled or exceeded the average Marshall densities; (3) furthermore, that most of the sections have neither equaled nor exceeded the gyratory design densities (except 100 psi - 30 gyrations compactive effort). It is believed that once the pavement reaches these gyratory values, flushing would be evidenced as indicated on the gyrographs at corresponding asphalt contents.

SUMMARY AND CONCLUSIONS

The primary purpose of this study was to investigate the effect of using high intensity pneumatic rollers for intermediate rolling on the density of asphaltic concrete pavement during construction and the corresponding effect of traffic on the densification and wheel path rutting subsequent to construction. Details of construction procedures and results at time of construction are reported in Reference 1.[2] This report is primarily concerned with the effect of traffic on the densification of the pavement after three years. The following hypothesis is advanced on the basis of findings from these periodic surveys and should be confined to the materials and conditions under study:

(1) Regardless of the number of passes (coverages of the pneumatic rollers), most of the increase in compaction of the pavement occurs during the first six months of traffic after which time this rate decreases with a tendency to taper off.

(2) Ibid.

(2) The densification under traffic is the least after six months of traffic for sections showing optimum condition during construction.

(3) For a given number of passes, the greatest magnitude of wheel path rutting was observed for sections compacted at 55 psi contact pressure.

(4) The 85 psi contact pressure consistently required less rolling coverage for optimum conditions. Likewise, for a given number of coverages 85 psi exhibited the least increase in compaction after 3-years of traffic and corresponding minimum wheel path rutting.

(5) Majority of the sections have reached 100% of the 75-blow plant and laboratory design density. However, none of the sections have reached the theoretical density of the pavement.

(6) Fluctuation in periodic density values indicate occurrence of some displacement of the pavement due to traffic particularly for sections on flexible base. However, none of the sections showed any evidence of flushing.

RECOMMENDATIONS

On the basis of some apparent trends discussed above and in the preceding paragraphs, the following recommendations seem justified at the present time although it should not be extrapolated without the benefit of further investigation on mixes containing different types of aggregate.

Use of 85 psi contact pressure for surface course as a minimum requirement for intermediate rolling with self-propelled pneumatic rollers. For binder course this contact pressure should be reduced to 75 psi to eliminate decompaction effect which was evidenced at 85 psi contact pressure.

The number of passes should be varied from 9 to 15 depending on the type of mix, quantity of asphalt, temperature of the mix and the ability of the pavement mat to withstand these high intensity rollers.

APPENDIX

TABLE I - AVERAGE TEST RESULTS OF WEARING COURSE MIXTURE ON SURFACE TREATMENT AND FLEXIBLE BASE

			PER CENT COMPACTION											
Section Number	No. of Passes	Per Cent Bitumen	50-Blow Compaction					75-Blow Compaction					% Voids*	36 Mo Grooves, mm
			Original	6 mo	15 mo	24 mo	36 mo	Original	6 mo	15 mo	24 mo	36 mo		
85 PSI CONTACT PRESSURE														
1	9	5.5	100.7	101.4	102.0	102.3	101.9	100.1	100.8	101.5	101.8	101.4	4.3	8.2
2	11	5.4	99.8	100.4	100.8	100.9	100.9	99.3	99.9	100.3	100.4	100.4	5.3	7.2
3	13	5.4	98.2	99.8	100.0	100.1	100.2	97.7	99.3	99.4	99.6	99.6	6.0	8.3
4	15	5.4	99.1	100.6	100.8	101.0	101.2	98.6	100.0	100.3	100.5	100.7	5.0	8.0
5	17	5.4	98.5	99.8	99.8	100.0	99.9	97.9	99.3	99.3	99.5	99.4	6.2	6.4
6	19	5.4	98.6	100.0	100.2	100.6	100.7	98.1	99.5	99.6	100.0	100.1	5.5	5.7
75 PSI CONTACT PRESSURE														
8	9	5.4	98.9	100.3	101.0	100.4	100.2	97.6	99.0	99.7	99.1	98.9	5.2	4.3
9	11	5.4	98.3	98.3	99.3	99.3	99.3	97.0	97.1	98.1	98.0	98.0	6.1	5.3
10	13	5.4	98.4	99.0	99.2	99.1	99.6	97.2	97.8	97.9	97.8	98.3	5.8	5.5
11	15	5.4	99.6	99.7	99.3	99.9	99.5	98.3	98.4	98.0	98.6	98.2	5.9	6.2
12	17	5.0	97.3	98.4	98.1	97.9	98.5	-	-	-	-	-	7.3	5.5
13	19	4.8	95.7	96.5	97.4	96.8	97.2	96.2	97.0	98.0	97.4	97.8	7.3	7.4

* Based on the apparent specific gravity of the aggregate

WEARING COURSE OVERLAYING A BINDER COURSE ON SURFACE TREATMENT AND FLEXIBLE BASE

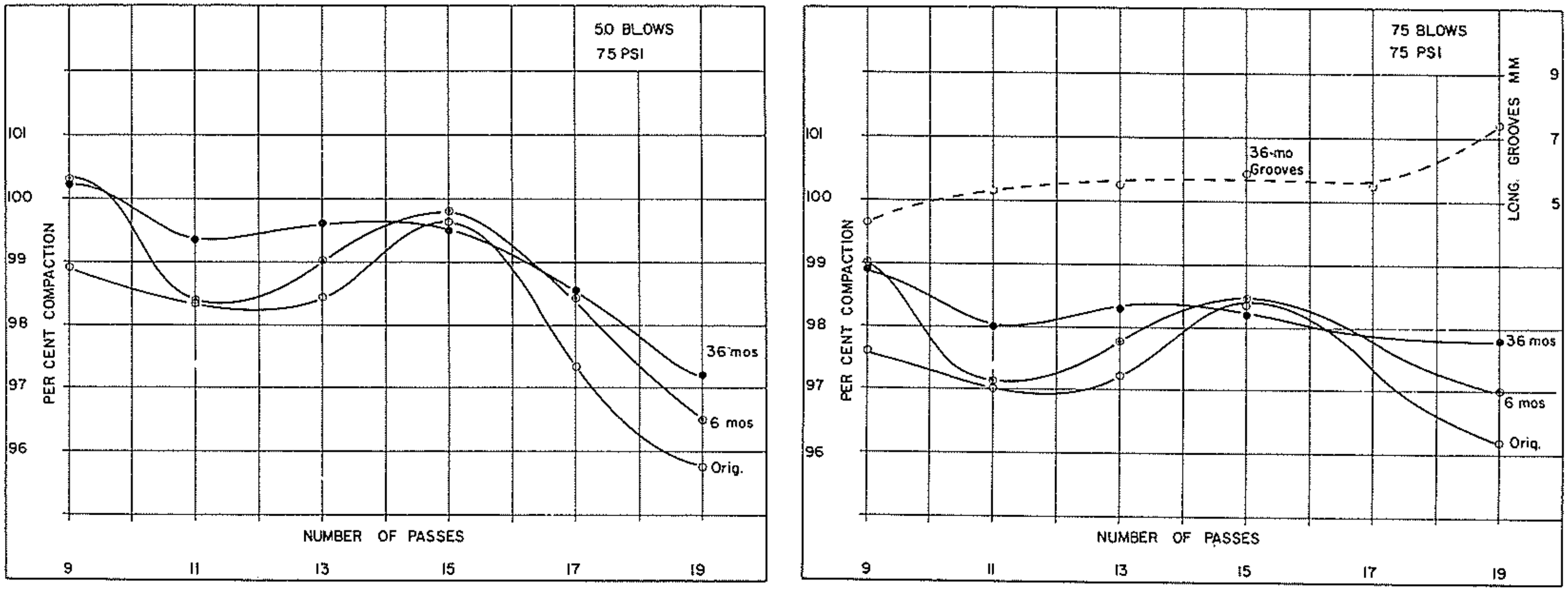

Figure 1 - Comparison of 6 and 36 month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

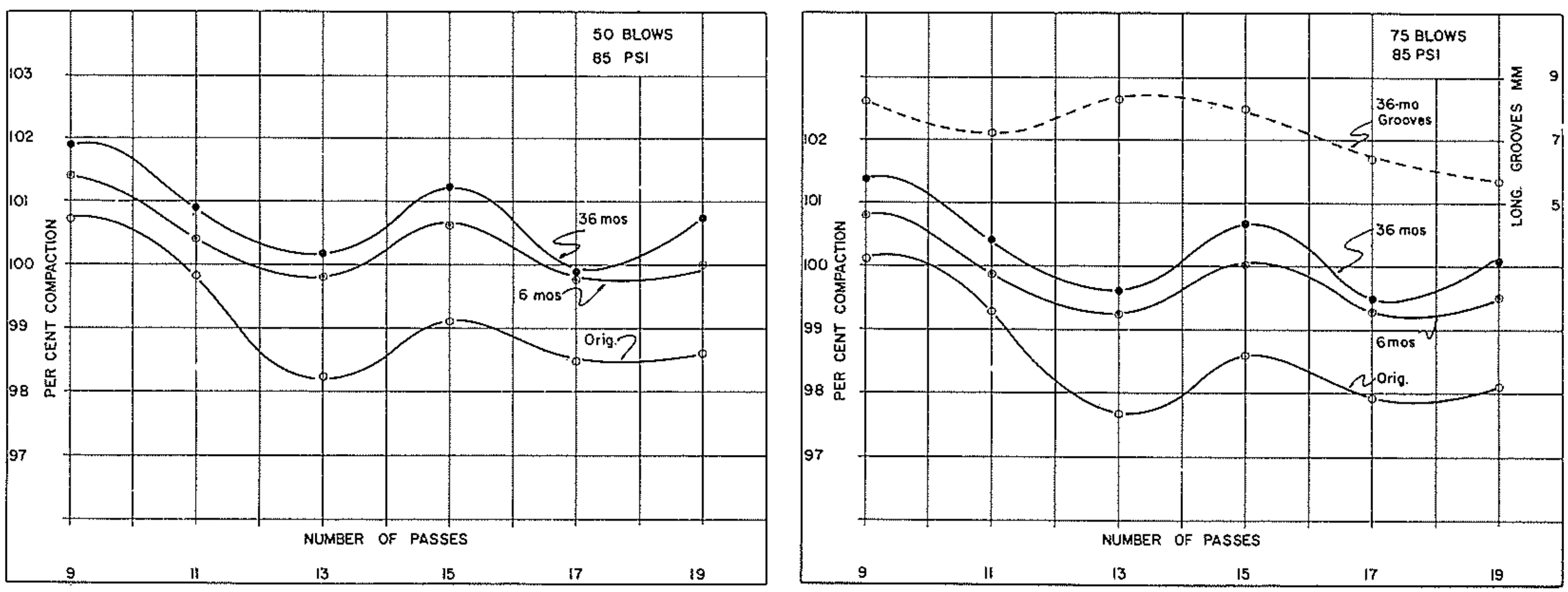

Figure 2 - Comparison of 6 and 36 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

TABLE II - AVERAGE TEST RESULTS OF WEARING COURSE MIXTURE ON CONCRETE BASE

Section Number	No. of Passes	Per Cent Bitumen	PER CENT COMPACTION: 50-Blow Compaction Original	50-Blow 6 mo	50-Blow 15 mo	50-Blow 24 mo	50-Blow 36 mo	75-Blow Compaction Original	75-Blow 6 mo	75-Blow 15 mo	75-Blow 24 mo	75-Blow 36 mo	% Voids	36 Mo Grooves, mm
75 PSI CONTACT PRESSURE														
15	19	5.8	97.8	101.2	101.4	101.8	101.4	97.5	100.8	101.1	101.5	101.1	5.2	6.8
16	17	5.8	98.2	101.2	102.1	102.5	101.9	97.8	100.9	101.7	102.2	101.6	4.8	7.2
17	15	5.8	97.4	101.0	101.3	101.6	102.0	97.1	100.6	100.9	101.2	101.7	4.7	6.7
18	11	5.8	97.0	100.3	101.2	100.8	101.7	96.7	100.0	100.8	100.5	101.4	4.9	7.4
19	19	6.0	99.2	100.6	101.4	101.4	101.4	98.0	99.4	100.2	100.2	100.3	3.9	6.3
20	17	6.0	98.5	100.7	101.2	101.5	101.1	97.3	99.5	100.0	100.3	99.9	4.3	6.8
21	15	6.0	97.0	100.6	101.1	101.8	102.0	95.9	99.4	99.9	100.6	100.8	3.4	6.9
22	11	6.0	99.1	100.6	101.2	101.4	101.8	98.0	99.4	100.0	100.2	100.6	3.6	7.6
85 PSI CONTACT PRESSURE														
23	7	6.0	97.8	100.2	101.0	101.3	101.6	97.5	99.9	100.6	101.0	100.8	3.5	6.0
24	9	6.0	98.6	100.0	101.1	101.7	102.1	98.3	99.7	100.7	101.3	100.7	3.0	7.5
25	11	6.0	96.9	99.9	100.8	101.3	101.4	96.6	99.5	100.4	101.0	100.9	3.7	8.4
26	15	6.0	97.7	100.4	100.8	101.4	101.9	97.3	100.1	100.4	101.0	100.8	3.1	6.5
27	7	5.8	99.0	101.8	102.3	102.8	103.1	97.6	100.4	101.1	101.4	101.7	4.2	6.8
28	9	5.8	100.3	102.6	102.9	103.2	103.0	98.9	101.1	101.5	101.8	101.6	4.2	5.5
29	11	5.8	99.9	102.7	103.0	103.2	103.3	98.5	101.3	101.6	101.8	101.9	4.0	6.6
30	15	5.8	99.8	102.7	102.8	103.1	103.1	98.5	101.4	101.4	101.7	101.7	4.2	5.7
55 PSI CONTACT PRESSURE														
31	15	6.0	97.5	101.2	101.5	102.4	102.0	95.7	99.4	99.7	100.6	100.2	3.9	8.2
32	17	6.0	98.4	100.8	101.4	102.0	102.4	96.7	99.0	99.6	100.2	100.6	3.5	9.2
33	19	6.0	99.6	100.4	101.4	102.2	102.7	97.8	98.6	99.6	100.4	100.9	3.2	6.3
34	15	5.8	99.1	101.0	102.0	102.4	102.7	97.4	99.3	100.3	100.7	101.0	3.3	7.7
35	17	5.8	99.1	100.5	101.5	101.9	102.0	97.4	98.8	99.7	100.2	100.3	4.0	8.3
36	19	5.8	98.8	101.3	101.9	102.1	102.5	97.1	99.5	100.2	100.3	100.8	3.5	6.4

WEARING COURSE OVERLAYING A BINDER COURSE ON CONCRETE RIGID BASE
75 PSI CONTACT PRESSURE

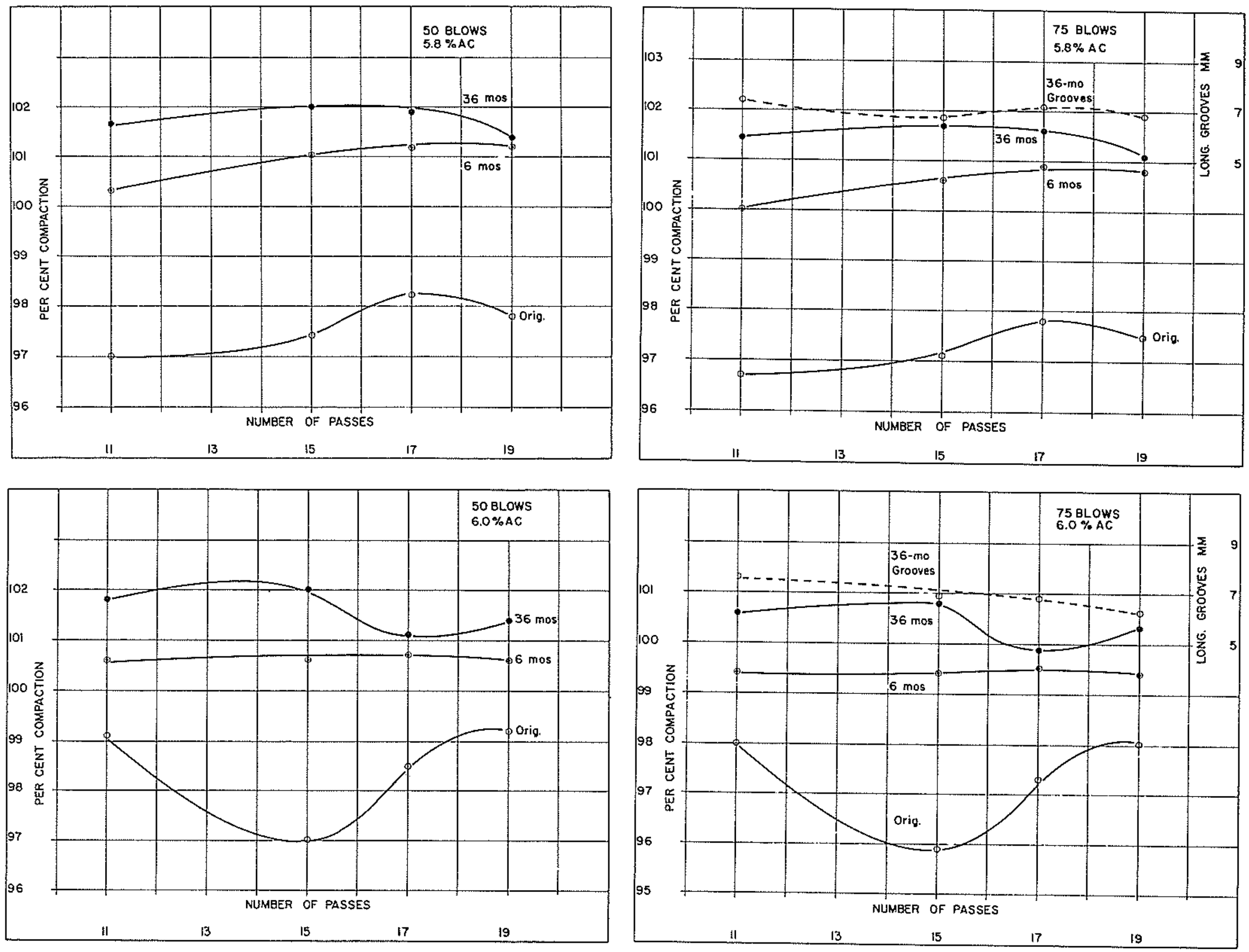

Figure 3 - Comparison of 6 and 36 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

WEARING COURSE OVERLAYING A BINDER COURSE ON CONCRETE RIGID BASE
85 PSI CONTACT PRESSURE

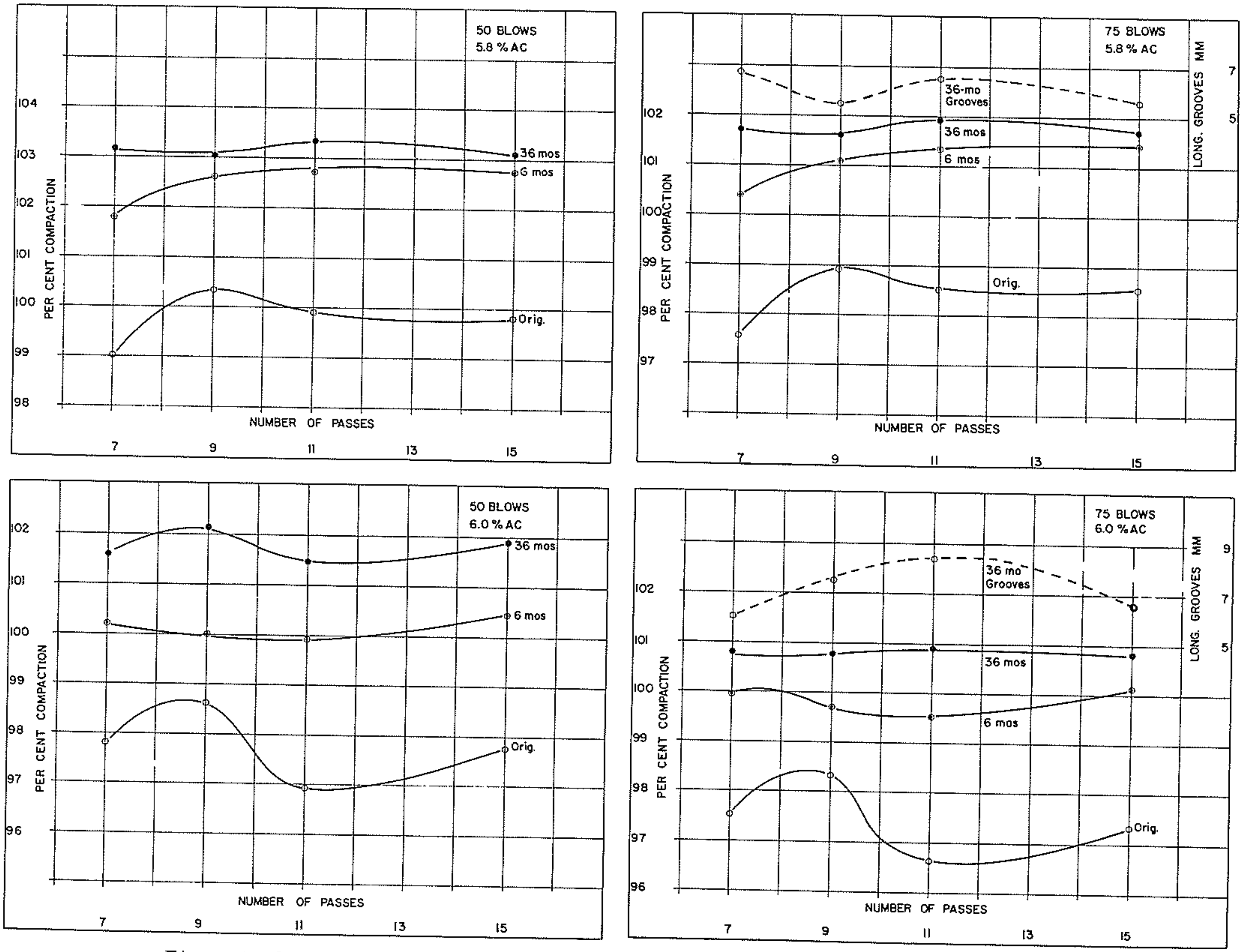

Figure 4 - Comparison of 6 and 36 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

WEARING COURSE OVERLAYING A BINDER COURSE ON CONCRETE RIGID BASE
55 PSI CONTACT PRESSURE

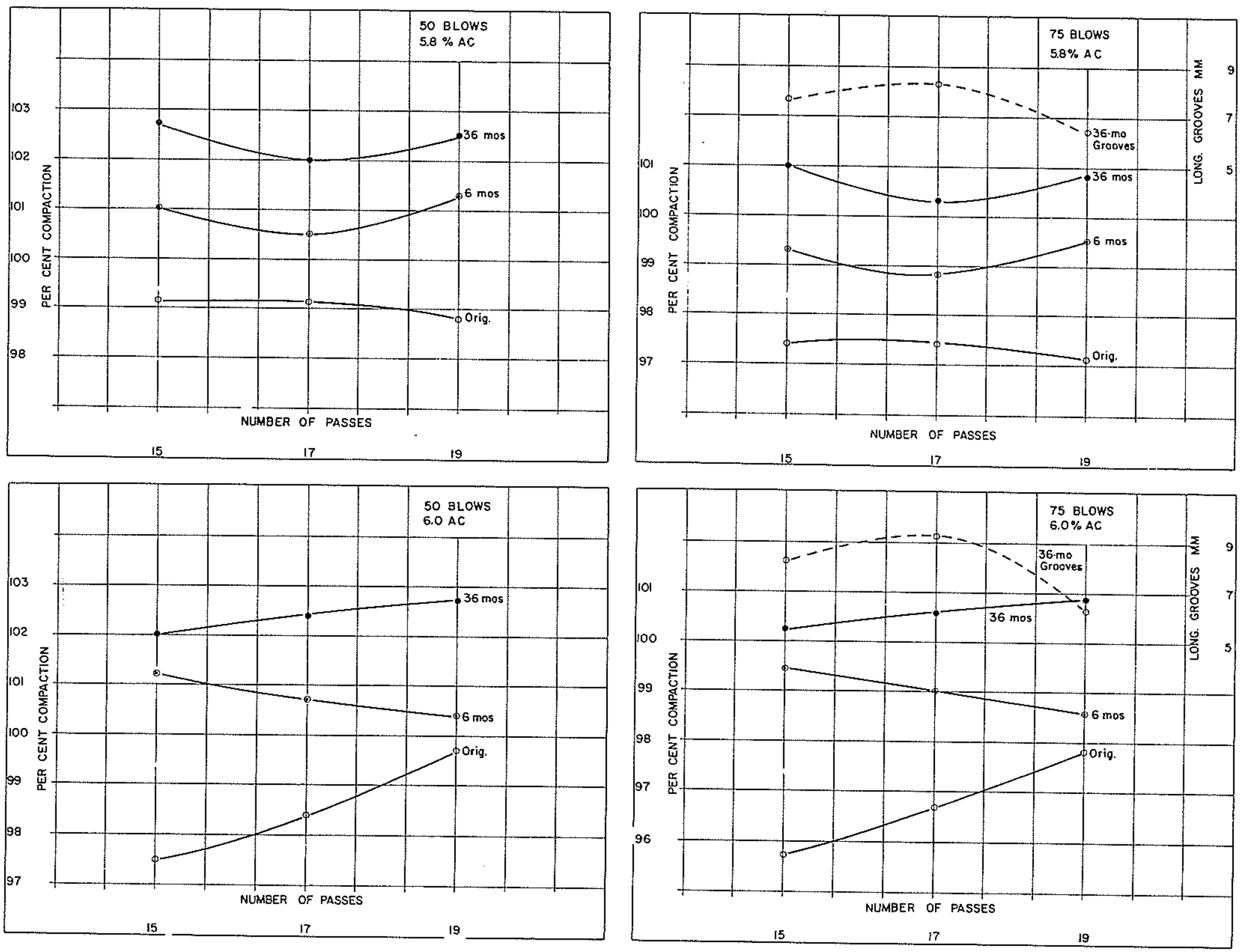

Figure 5 - Comparison of 6 and 36 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

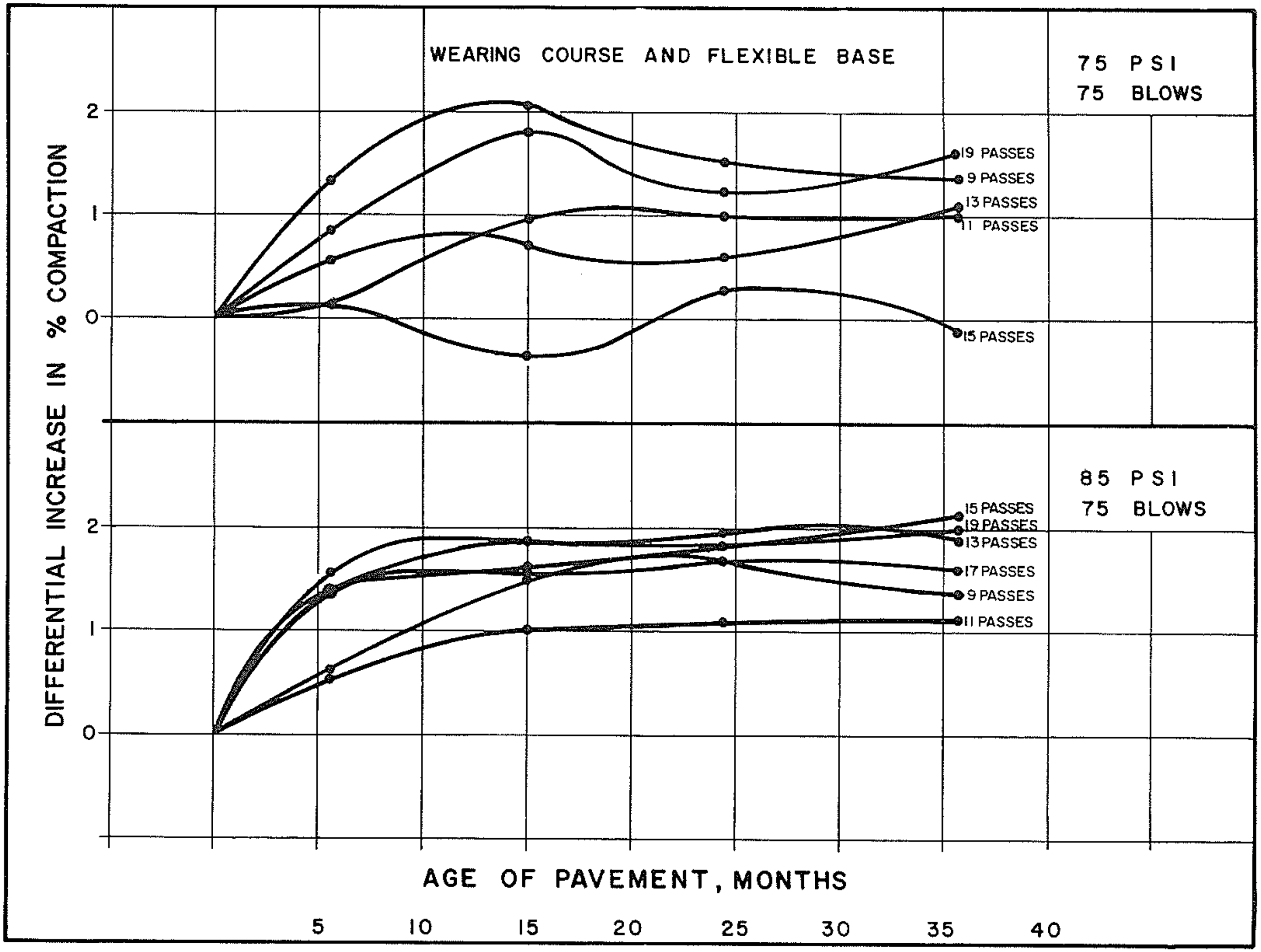

Figure 6 - Pavement Age Versus Differential Increase in Average Compaction (from the original) Relationships for Different No. of Passes.

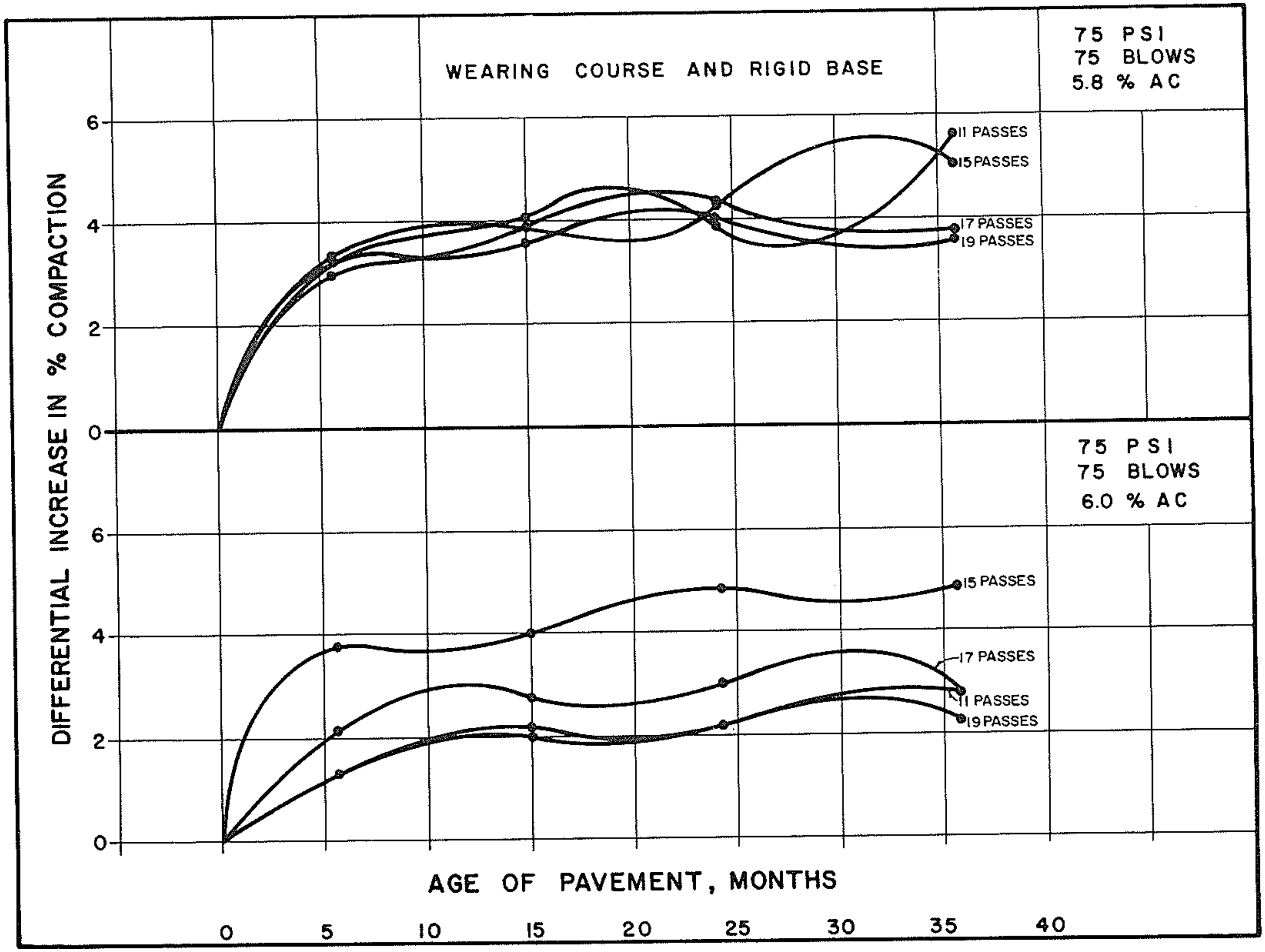

Figure 7 - Pavement Age Versus Differential Increase in Average Compaction (from the original) Relationships for Different No. of Passes.

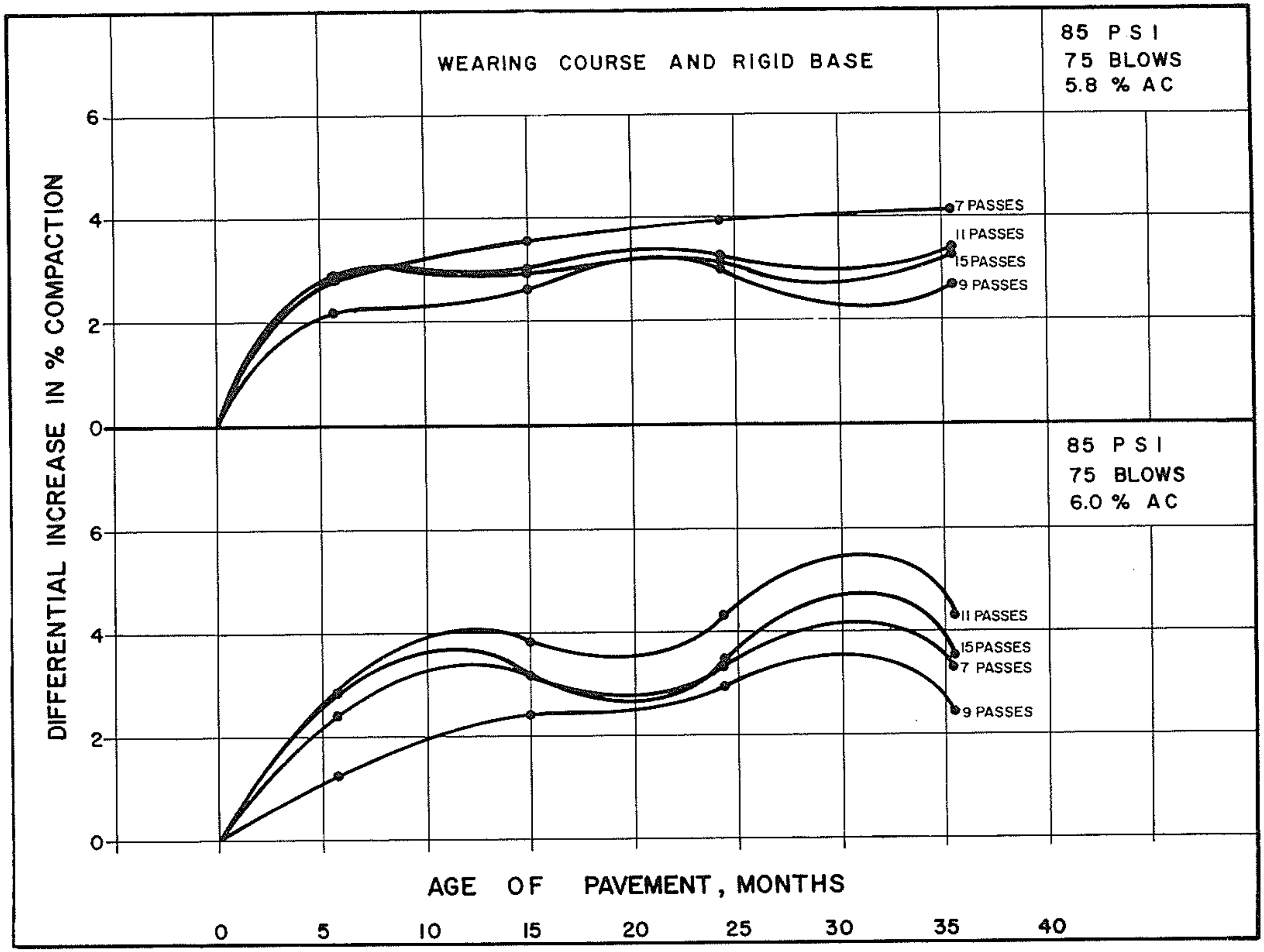

Figure 8 - Pavement Age Versus Differential Increase in Average Compaction (from the original) Relationships for Different No. of Passes.

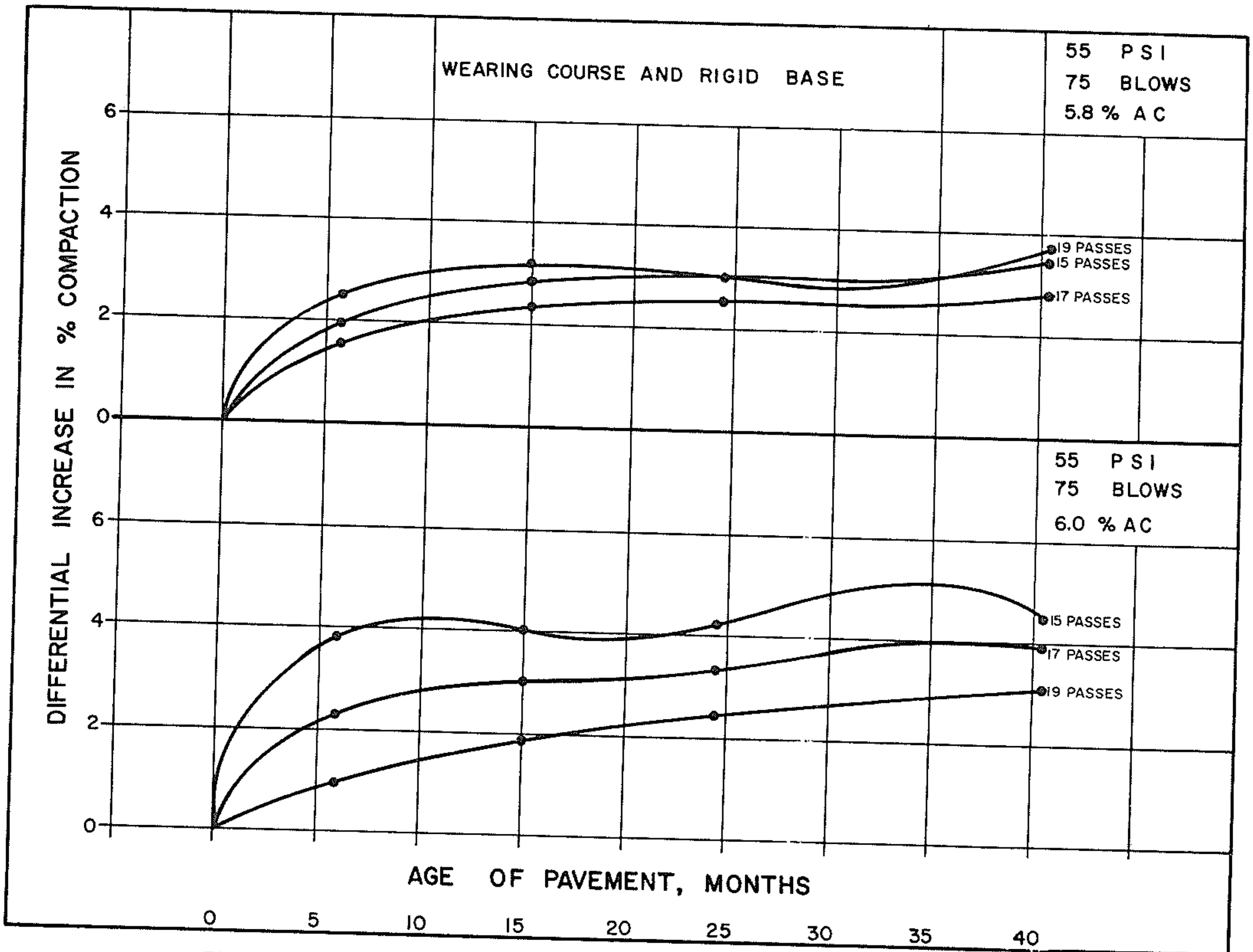

Figure 9 - Pavement Age Versus Differential Increase in Average Compaction (from the original) Relationships for Different No. of Passes.

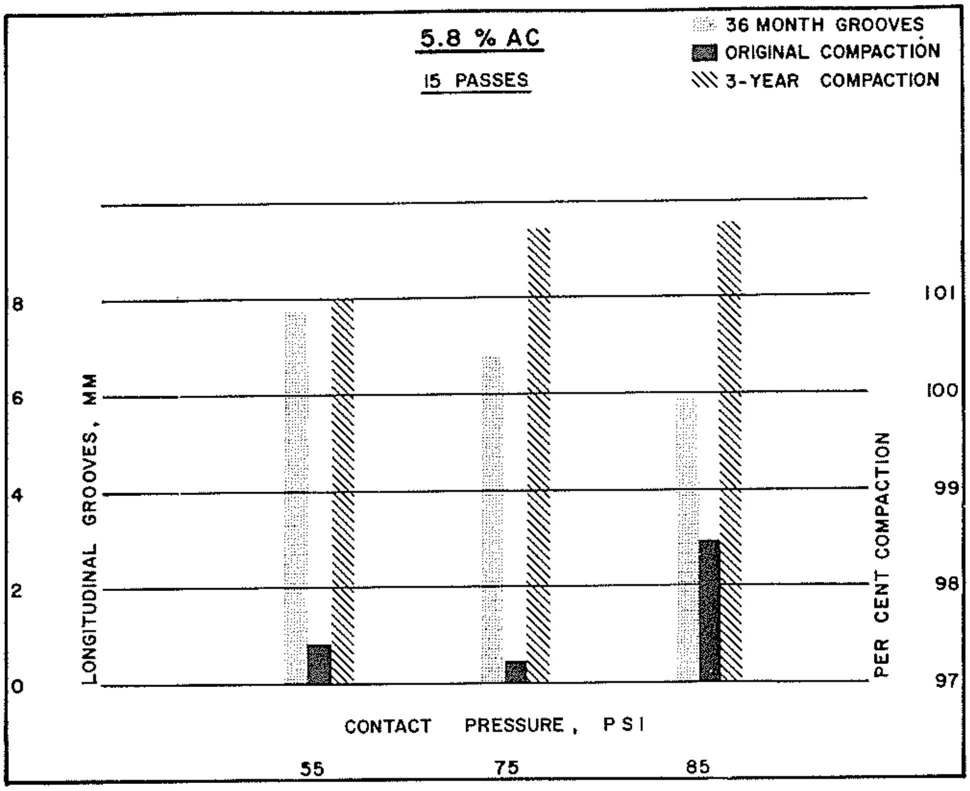

Figure 10 - Comparison of Average Wheel Path Rutting and Original and 36-month Average Compaction for Different Field Compactive Efforts (Wearing Course and Rigid Base).

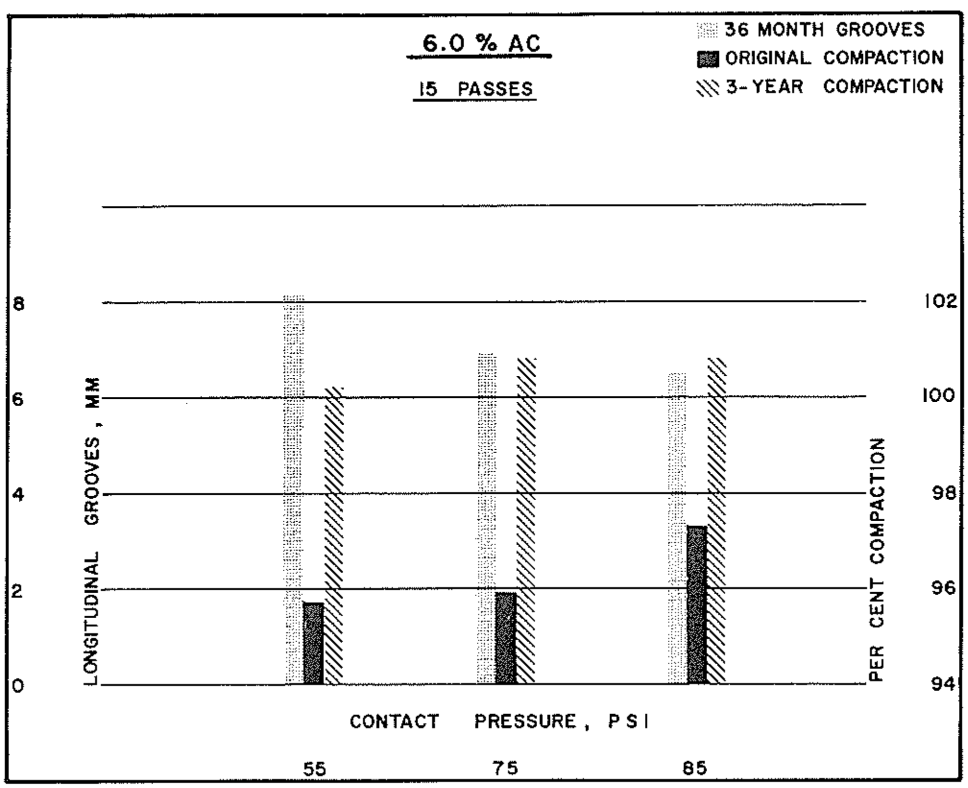

Figure 11 - Comparison of Average Wheel Path Rutting and Original and 36-month Average Compaction for Different Field Compactive Efforts (Wearing Course and Rigid Base).

TABLE III - AVERAGE TEST RESULTS OF BINDER COURSE MIXTURE ON SURFACE TREATMENT AND FLEXIBLE BASE

Section Number	No. of Passes	Percent Bitumen	PERCENT COMPACTION 50 Blow Compaction Orig	6 Mo	15 Mo	75 Blow Compaction Orig	6 Mo	15 Mo	% Voids
85 PSI	Contact Pressure:								
37	11	4.3	99.3	98.6	99.6	98.9	98.2	99.2	5.8
38	9	4.3	100.0	99.0	99.8	99.6	98.6	99.4	5.6
39	13	4.3	98.3	99.8	100.1	97.9	99.4	99.7	5.3
40	15	4.3	98.6	99.6	99.4	98.2	99.2	99.0	6.0
41	17	4.3	99.1	100.6	99.9	98.7	100.1	99.5	5.5
75 PSI	Contact Pressure:								
42	9	4.4	99.5	100.2	100.3	99.0	99.7	99.8	5.6
43	11	4.3	99.1	100.1	100.0	98.7	99.7	99.5	6.0
44	13	4.3	100.2	100.1	100.3	99.7	99.7	100.0	5.5
45	15	4.3	98.7	99.9	99.4	98.2	99.4	98.9	6.6
46	17	4.3	98.3	99.8	99.7	97.8	99.4	99.2	6.2

TABLE IV - AVERAGE TEST RESULTS OF BINDER COURSE MIXTURE ON CONCRETE BASE

Section Number	No. of Passes	Percent Bitumen	PERCENT COMPACTION 50 Blow Compaction Orig	6 Mo	15 Mo	75 Blow Compaction Orig	6 Mo	15 Mo	% Voids
85 PSI	Contact Pressure:								
47	13	4.3	99.6	99.7	99.4	100.4	100.4	100.1	6.2
48	11	4.3	100.5	100.0	100.1	101.2	100.7	100.9	5.5
49	9	4.3	99.5	100.3	100.2	100.2	101.0	101.0	5.5
50	15	4.3	99.8	100.3	99.6	100.6	101.0	100.3	6.1
51	17	4.3	99.7	100.8	99.2	100.5	101.5	100.0	6.4
75 PSI	Contact Pressure:								
52-55	17	4.3	99.0	100.0	100.2	99.1	100.0	100.4	5.6
53	15	4.3	99.9	99.9	100.0	100.0	100.0	100.1	5.6
54-57	11	4.3	99.2	100.3	99.9	99.3	100.3	100.0	5.8
56	13	4.3	99.7	100.3	100.2	99.8	100.4	100.3	5.5
58	9	4.3	99.6	100.4	99.9	99.7	100.5	100.0	5.8

BINDER COURSE ON SURFACE TREATMENT AND FLEXIBLE BASE

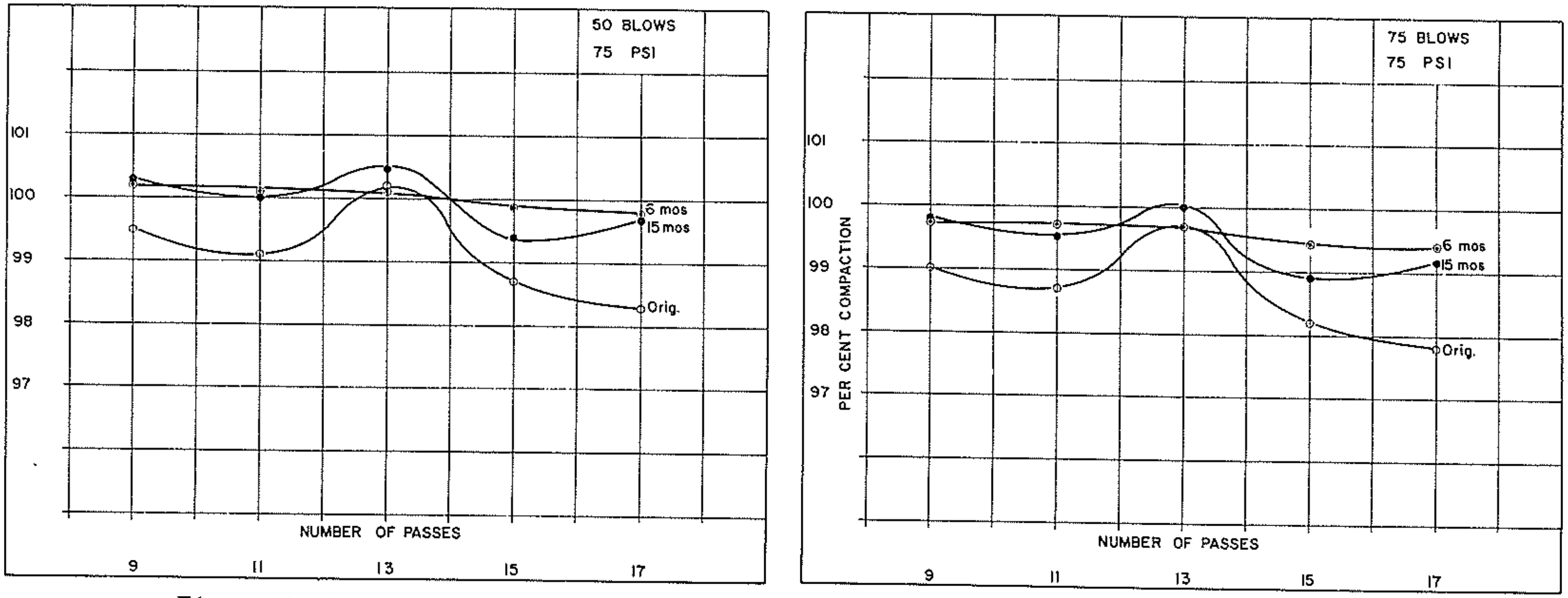

Figure 12 - Comparison of 6 and 15 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

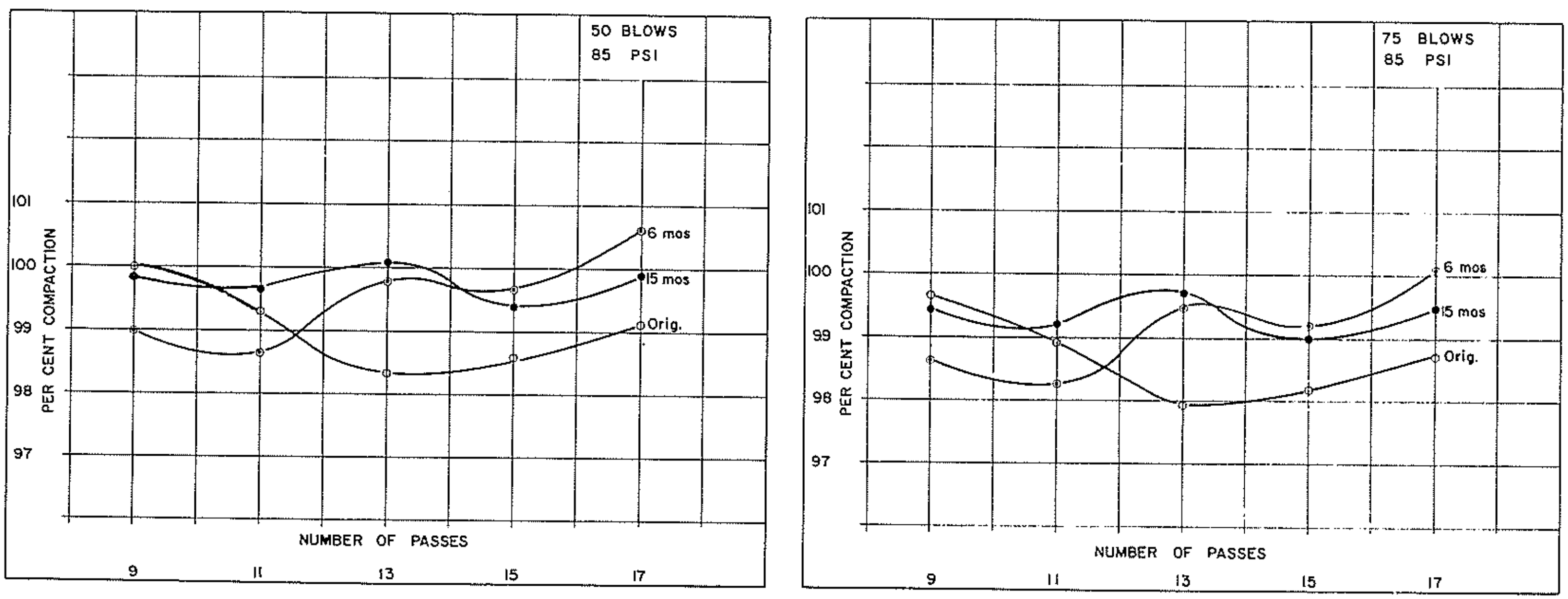

Figure 13 - Comparison of 6 and 15 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

BINDER COURSE ON CONCRETE RIGID BASE

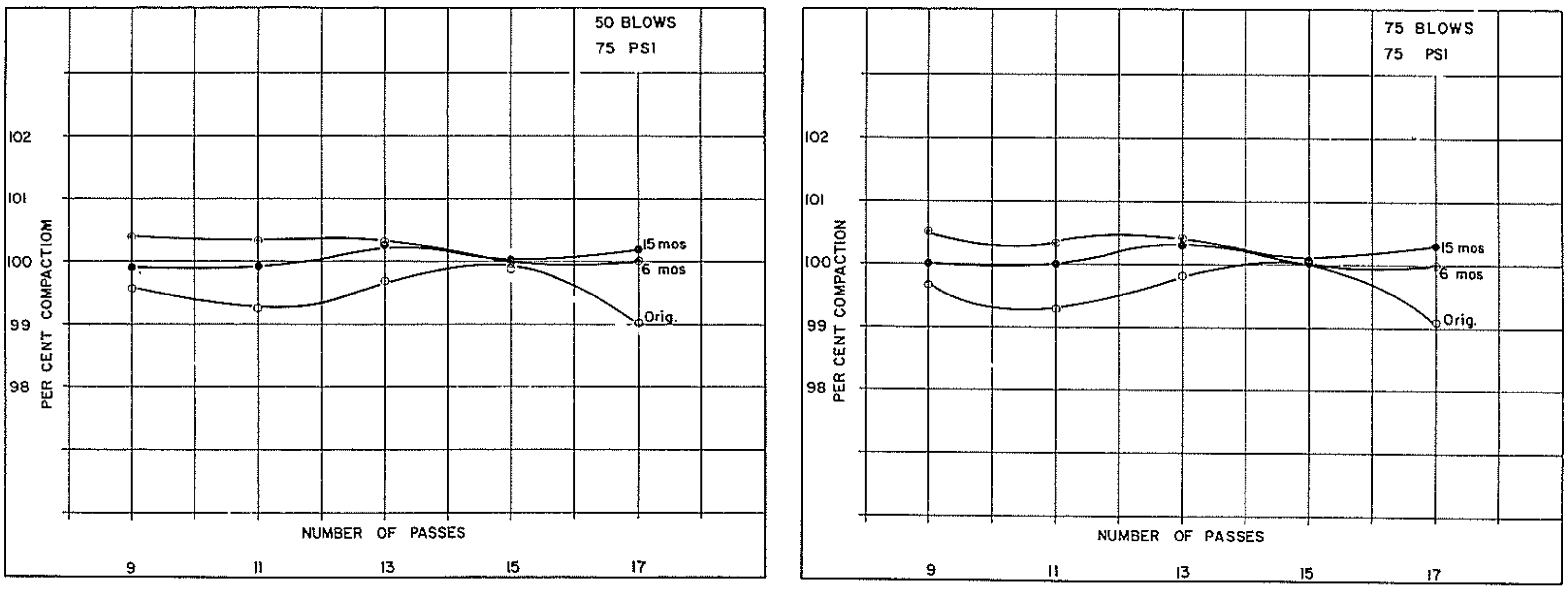

Figure 14 - Comparison of 6 and 15 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

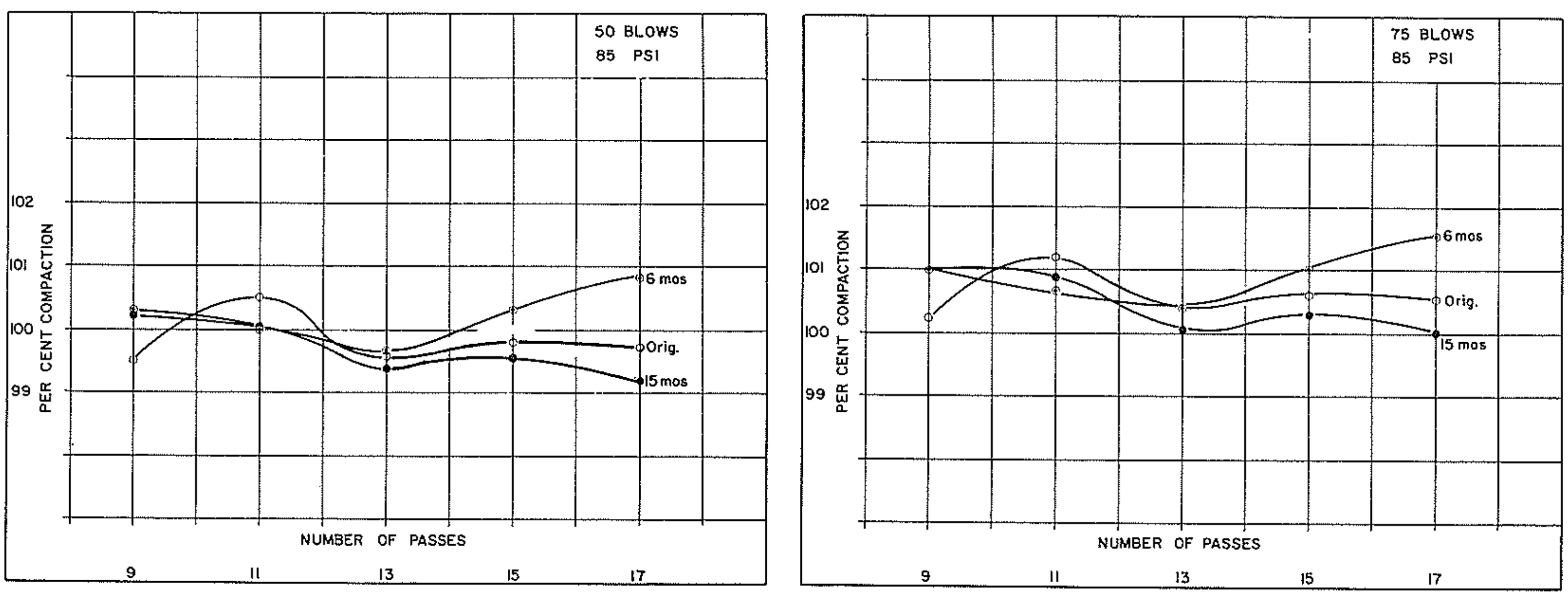

Figure 15 - Comparison of 6 and 36 Month Average Compaction With The Average Compaction Obtained During Construction Versus the No. of Passes at Time of Construction.

TABLE V - COMPARISON OF LABORATORY DESIGN DENSITY AND OPTIMUM FIELD DENSITY

Cont. Press. psi	Base Type	Opt. No. of Passes	% Bitumen	Field Density, pcf	DESIGN DENSITY, pcf									
					50-blow		75-blow		Gyratory, psi/gyrations					
					Plant	Lab.	Plant	Lab.	100/30	100/60	200/30	200/60	250/30	250/60
WEARING COURSE MIX - 36 MONTH VALUES														
75	Flexible	15	5.4	142.1	142.0.	142.4	143.1	143.9	-	145.4	145.2	146.1	145.8	146.2
85	Flexible	9	5.5	144.5	142.1	142.6	143.2	143.9	145.9	145.6	145.2	146.1	145.8	146.1
55	Rigid	17 19	5.8 6.0	144.0 144.9	142.0 141.7	142.9 142.9	143.4 143.2	143.7 143.6	144.4 144.6	145.3 144.9	145.2 145.1	145.7 145.5	145.2 145.6	145.8 145.5
75	Rigid	17 19	5.8 6.0	142.9 143.8	142.0 141.7	142.9 142.9	143.4 143.2	143.7 143.6						
85	Rigid	9 9	5.8 6.0	143.7 145.3	142.0 141.7	142.9 142.9	143.4 143.2	143.7 143.6						
BINDER COURSE MIX - 15 MONTH VALUES														
75	Flexible	13	4.3	145.3	145.0	143.4	145.2	143.5	144.8	146.2	146.5	147.1	146.5	147.3
85	Flexible	9	4.3	145.2										
55	Rigid	17	4.3	145.3										
75	Rigid	15	4.3	145.1										
85	Rigid	11	4.3	145.3										

Theoretical Density of the Mix - 153.8 lb/cu ft @ 4.3% AC
151.1 lb/cu ft @ 5.0% AC
151.0 lb/cu ft @ 5.5% AC
150.1 lb/cu ft @ 5.8% AC
149.7 lb/cu ft @ 6.0% AC

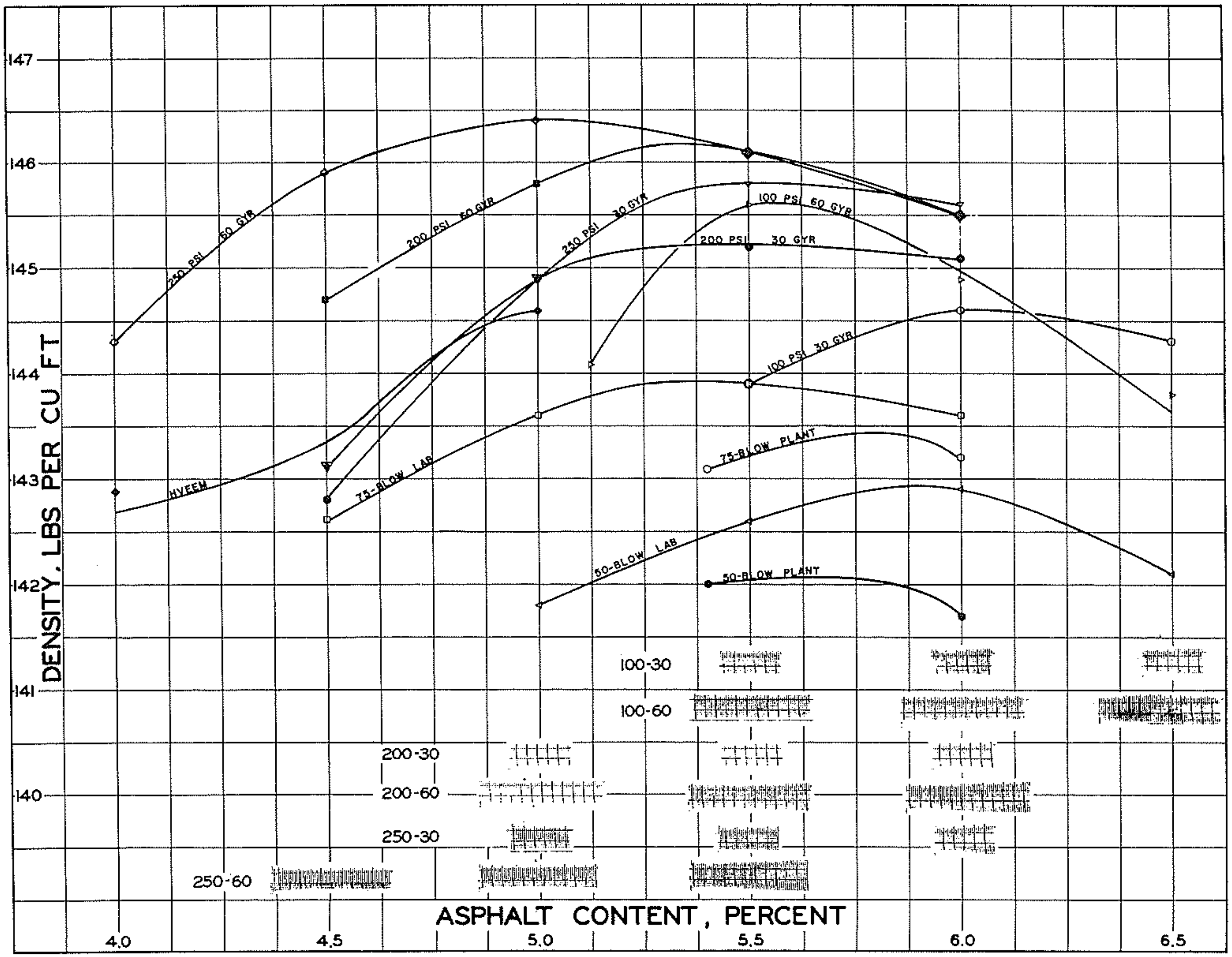

Figure 16 - Comparison of Wearing Course Densities for Various Types of Laboratory Compaction.

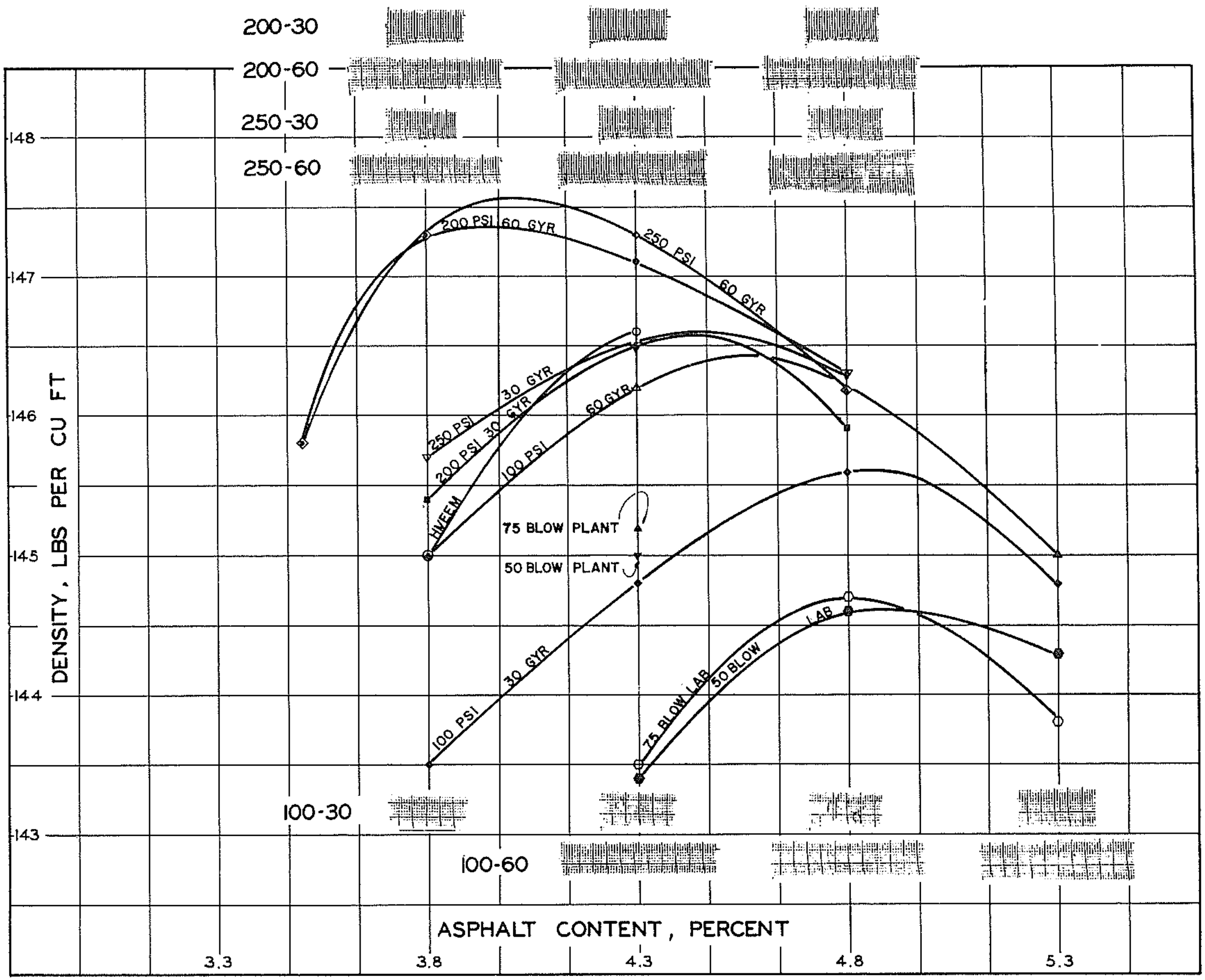

Figure 17 - Comparison of Binder Course Densities for Various Types of Laboratory Compaction.

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