Research Report No. 10

COMPACTION OF ASPHALTIC CONCRETE PAVEMENT WITH HIGH INTENSITY PNEUMATIC ROLLER PART I

by

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SYNOPSIS

With a view to eliminate or minimize rutting of asphaltic concrete pavement, the need for improvement in production of mixes and rolling procedures seemed warranted. This project was initiated to study the effects of compactive efforts using a high intensity pneumatic roller on the asphaltic concrete pavement and further investigate the possibility of correlating different compactive procedures presently used in the laboratory with those in the field. While this project as a whole is incomplete in that periodic observations are to be made over a period of five years, the most important phase of the study, namely the field analysis and laboratory correlation analysis is complete. Also included in this report is the first periodic survey (six month).

Based on the construction and six month results, it was found that on the average, contact pressures in excess of 75 psi give maximum per cent of pavement compaction with less coverages than those with 75 and lower. Furthermore, the densification under traffic was the least after six months for sections showing optimum conditions during construction. The high intensity roller showed no detrimental effects to the base at any stage of the construction nor any surface irregularities after six months of traffic.

No definite correlation was indicated at this early stage in the investigation between laboratory compaction and field compaction. Perhaps subsequent periodic surveys may help in

better evaluation of this aspect.

Another important finding from the study was the wide variation in results observed in spite of close control - particularly with respect to plant mixed specimens. Such variations, inherent or otherwise, necessitates a need for improved quality control study for establishing criteria limits and the number of samples necessary to ascertain that the specifications are met.

INTRODUCTION

Recent experience has indicated that, in general, rollers used in compacting hot mix asphaltic concrete should be capable of exerting pressures comparable to that used by the rolling stock on the highways. The traffic survey conducted during the summer of 1959, indicated that axle loads of up to 24,000 lb. or wheel loads of 6,000 lb. and tire inflation pressures of up to 115 psi are being encountered on the highways at service temperatures. This results in a contact pressure of 120 psi on the pavement for maximum conditions and 75-85 psi for average conventional loaded truck conditions. The pneumatic tire rollers hitherto in use in Louisiana with 2,000 lb. wheel load and 55 psi inflation pressure exert anywhere from 37-55 psi of contact pressure, a range well below that imposed by the conventional type truck tires(1)*. 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.

Three of the most important factors which influence the stability of asphaltic concrete pavements in service other than the quality of the mixture, are:

1. The magnitude of the compactive effort employed during construction.
2. The temperature of the mixture during construction.
3. The number of passes applied with the compaction equipment.

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* Numbers in parentheses refer to list of references

The first phase of the investigation is mainly concerned with the first and the third item, utilizing pneumatic rollers with ground or contact pressure concept rather than inflation pressure. Also, for better production of the so called nonrutting mixes, the importance of the first two factors mentioned above could not be overlooked since they greatly influence the physical characteristics of the mixture in the laboratory. Therefore, the second phase of this study is concerned with the evaluation and correlation of field compactive effort with laboratory compactive efforts utilizing different methods and degrees of compaction currently employed.

PURPOSE OF STUDY

The purpose of this investigation was to:

1. Determine the magnitude of the compactive effort and the number of passes required in the field to obtain optimum density using a high intensity pneumatic roller.
2. Effect a correlation between the field and the laboratory compactive effort utilizing different methods of compaction.
3. Establish the optimum degree of laboratory compaction and design criterion for high intensity rollers as based on the rate and degree of densification obtained under traffic.

SCOPE OF THE STUDY

In 1961, the study was initiated as a research project with funds made available by the Bureau of Public Roads and the Louisiana Department of Highways. The investigation was conducted on sixty-one test sections of hot-mix, hot-laid asphaltic concrete pavement consisting of a 1.5 inch wearing course overlaying a binder course of 2.5 inches in thickness on flexible and rigid base. Thus, the following four conditions were surveyed, two for each mix type.

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 on binder course on flexible base.
4. Fifteen sections on binder course on rigid base.

Preliminary investigation on the above sections was concluded in January 1962 on State Project 13-10-24, Covington-Robert Highway on U S 190, six months after which the first periodic survey was conducted to study the effects of traffic on the densification of the aforementioned test sections.

PROCEDURE

Field Investigation

Special Equipment - It was originally planned to use a 30-ton pneumatic roller, but prevailing specifications required the use of a 9-ton pneumatic roller for intermediate rolling. Since the purpose of this project was to study the effect of compactive efforts on asphaltic concrete pavements, and that the contact pressure is the controlling factor and not the gross weight of the rollers, it was decided to continue using the same, Bros-SP 54 self-propelled pneumatic tire roller with 14 ply tires, the general specifications for which are given below:

Rolling width	68 in
Empty weight	6,600 lb
Maximum gross weight	18,000 lb
Number of wheels	
Front	5
Rear	4
Tire size	7.50-15
Tire ply rating	14

The roller weight was kept constant at 2,000 lb/wheel and the tire pressures were varied to give 55, 75 and 85 psi contact pressures. Conversion charts, supplied by the tire manufacturers, were used in obtaining the necessary information on contact pressures from inflation pressures.

Selection of Test Sections - Straight stretches of the roadway on both lanes were selected as test sections and attention was given to keep these sections away from the existing roadway turn-outs and intersections to minimize any additional compaction.

Plant Control - Every thirty minutes, after taking the temperature of the mix, trucks leaving the plant were sampled and given a number for identification on the road. A minimum of two specimens were molded at each Marshall compactive effort of 50 and 75 blows per end of specimen. The molded specimens and bituminous mixture were then tested for:

1. Specific Gravity - LDH Designation TR 304-58
2. Marshall Stability and Flow - LDH Designation TR 305-58
3. Thickness
4. Bitumen Content and Gradation Analyses - LDH Designations TR 307-58 and TR 309-58, respectively

Test Site Control - Trucks sampled and numbered at the plant were identified on the road and the temperatures were recorded immediately after spreading. Specification requirements were strictly adhered to before any mix was laid down. Temperature recording was accomplished by means of a thermocouple sensitive to 1°F placed in the middle of the lift and a Leeds and Northrup Potentiometer. Each test section was approximately 100 feet long with one thermocouple to a section.

Rolling - Immediately after the mix was spread and the temperature recorded, breakdown rolling was started with the 3-wheel roller. Seven passes were used on all test sections. Passes of the pneumatic roller and the contact pressures were the only variables in the investigations. The number of passes was controlled carefully and varied, based on test results of the preceding sections. A tandem roller completed the rolling operation with seven passes. Temperatures were recorded before and after each sequence of rolling.

Samples - Twelve to 24 hours after spreading a minimum of three samples were obtained at the center line of the lane from each test section by means of a high speed diamond core drill.

Difficulties Encountered

In the initial stages of the investigation, considerable difficulty was encountered in regulating the plant to run smoothly. Hence, of the 82 trucks sampled, the first nine which were laid on the first day had to be discarded due to frequent changes in asphalt content, batch proportions, etc. Also, difficulty was encountered on the road in keeping close control of the compactive effort. Some trucks, although sampled at the plant, were not laid on the road, and hence, no section corresponding to those trucks was laid even though they were numbered. Most of these were due to mishaps such as flat tires and breakdowns.

Laboratory Investigation for Correlation Study

Materials (aggregate, mineral filler and asphalt cement) obtained during the construction phase of the project were used in molding specimens, a minimum of three for each asphalt content and in increments of 0.5%. The following methods of compaction were used in molding these specimens:

1. Marshall Method - LDH Designation TR 305-58
2. Hveem Method - California 304-B
3. Gyratory Kneading Compactor

The first two of these are the more familiar ones, whereas the third one, the Gyratory Kneading Compactor is, in brief, a combination compaction and testing machine which produces test specimens by a kneading process representative of the actual pavement structure. The degree of plasticity of bituminous mixtures can be determined directly by the application of a vertical pressure and a given number of gyrations. This provides a direct evaluation of the plastic properties of the specimens during compaction by means of a gyrograph which is a recording of the gyratory motion of the machine and thus indicates the critical asphalt content.

In molding the specimens by the above three methods, care was exercised in keeping the temperature, time and the method of mixing constant while varying the method of compaction, compactive effort and asphalt content. Table I shows summary of the compactive efforts, asphalt contents, mixing temperature, time, etc.

All specimens molded by the three methods were tested for specific gravity. The gyratory and Marshall specimens were further tested for Marshall stability and flow. The Hveem specimens were tested for stabilometer and cohesiometer values using California Test Methods, California 304-B and 306-B.

Six-Month Survey

Six months after the completion of the field investigation, the first periodic survey was conducted on the test sections to study the effect of traffic on the densification of the sections. The survey included, 1) measurement of longitudinal grooves by means of a straight edge and a scale, 2) cutting cores with a high speed diamond core drill, two from each tire path and one from the center line for wearing course mixture giving a total of five and one from each tire path and one from the center line for binder course mixture for a total of three, and 3) observation of surface conditions. The roadway samples were further tested for the properties shown under plant control.

TEST RESULTS

Complete results of plant, roadway and laboratory compacted

TABLE I

METHOD OF COMPACTION AND VARIABLES EMPLOYED IN MOLDING SPECIMENS

Compaction Method	Vertical Pressure, psi	No. of Gyrations, Blows or Tamps	Per Cent Bitumen (In Increments of 0.5)	
			Wearing Course	Binder Course
Marshall	-	50	5.0 - 6.5	4.2, 4.5, 4.8, 5.2
	-	75	4.5 - 6.0	4.3 - 5.3
Hveem	500	150	4.0 - 5.0	3.8 - 4.3
Gyratory - 1 Degree Angle	100	30	5.5 - 6.5	3.8 - 5.3
		60	5.0 - 6.5	3.8 - 5.3
	200	30 and 60	4.5 - 6.0	3.8 - 4.8
	250	30	4.5 - 6.0	3.8 - 4.8
		60	4.0 - 6.0	3.5, 3.8 - 4.8

Asphalt Cement Grade - 80 - 100 Pen
Mixing Temperature - 315 F
Mixing Time - 105 Secs
Mixing Method - Mechanical

TABLE II

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

Truck No.	Sect No.	Disch Temp, Deg Fahr	Rolling Temp, Deg Fahr		No. of Passes	Contact Press, psi	Per Cent Bitumen	Rdwy Gravity		Per Cent Compaction					
										50 Blow*			75 Blow**		
			3 Wheel	Pneum				Orig	6-Mon	Orig	6-Mon	Change	Orig	6-Mon	Change
47	13	300	174	158	19	75	4.8	2.209	2.228	95.7	96.5	0.8	96.2	97.0	0.8
48	12	345	266	194	17	75	5.0	2.246	2.270	97.3	98.4	1.1	-	-	-
49	11	315	227	182	15	75	5.4	2.280	2.282	99.6	99.7	0.1	98.3	98.4	0.1
50	10	315	211	175	13	75	5.4	2.253	2.267	98.4	99.0	0.6	97.2	97.8	0.6
51	9	335	186	166	11	75	5.4	2.249	2.251	98.3	98.3	0.0	97.0	97.1	0.1
52	8	315	246	170	9	75	5.4	2.264	2.296	98.9	100.3	1.4	97.6	99.0	1.4

*Average specific gravity of plant specimens 50 and 52 using 50 blow Marshall compaction 2.289
**Average specific gravity of plant specimens 49 and 51 using 75 blow Marshall compaction 2.319

Truck No.	Sect No.	Disch Temp, Deg Fahr	Rolling Temp 3 Wheel	Rolling Temp Pneum	No. of Passes	Contact Press, psi	Per Cent Bitumen	Rdwy Gravity Orig	Rdwy Gravity 6-Mon	50 Blow* Orig	50 Blow* 6-Mon	50 Blow* Change	75 Blow** Orig	75 Blow** 6-Mon	75 Blow** Change
55	6	320	194	160	19	85	5.4	2.240	2.272	98.6	100.0	1.4	98.1	99.5	1.4
56	5	320	261	191	17	85	5.4	2.237	2.268	98.5	99.8	1.3	97.9	99.3	1.4
57	4	290	242	183	15	85	5.4	2.252	2.285	99.1	100.6	1.5	98.6	100.0	1.4
58	3	345	241	198	13	85	5.4	2.231	2.268	98.2	99.8	1.6	97.7	99.3	1.6
59	2	325	218	174	11	85	5.4	2.268	2.282	99.8	100.4	0.6	99.3	99.9	0.6
60	1	345	240	195	9	85	5.5	2.287	2.303	100.7	101.4	0.7	100.1	100.8	0.7

*Average specific gravity of plant specimens 53, 55, 57 and 59 using 50 blow Marshall compaction 2.272
**Average specific gravity of plant specimens 54, 56, 58 and 60 using 75 blow Marshall compaction 2.284

TABLE III

AVERAGE TEST RESULTS OF WEARING COURSE MIXTURE ON CONCRETE BASE

Truck No.	Sect No.	Disch Temp, Deg Fahr	Rolling Temp, Deg Fahr		No. of Passes	Contact Press, psi	Per Cent Bitumen	Rdwy Gravity		Per Cent Compaction					
										50 Blow*			75 Blow**		
			3 Wheel	Pneum				Orig	6-Mon	Orig	6-Mon	Change	Orig	6-Mon	Change
61	22	310	265	160	11	75	6.0	2.252	2.286	99.1	100.6	1.5	98.0	99.4	1.4
62	21	315	243	165	15	75	6.0	2.204	2.286	97.0	100.6	2.4	95.9	99.4	2.5
63	20	310	253	176	17	75	6.0	2.237	2.287	98.5	100.7	2.2	97.3	99.5	2.2
64	19	295	273	191	19	75	6.0	2.254	2.286	99.2	100.6	1.4	98.0	99.4	1.4

*Average specific gravity of plant specimens 61 and 63 using 50 blow Marshall compaction 2.272
**Average specific gravity of plant specimens 62 and 64 using 75 blow Marshall compaction 2.299

65	18	325	168	134	11	75	5.8	2.180	2.254	97.0	100.3	3.3	96.7	100.0	3.3
66	17	325	231	193	15	75	5.8	2.189	2.269	97.4	101.0	3.6	97.1	100.6	3.5
67	16	315	236	161	17	75	5.8	2.206	2.275	98.2	101.2	3.0	97.8	100.9	3.1
68	15	310	241	189	19	75	5.8	2.198	2.273	97.8	101.2	3.4	97.5	100.8	3.3

*Average specific gravity of plant specimens 65 and 67 using 50 blow Marshall compaction 2.247
**Average specific gravity of plant specimens 66 and 68 using 75 blow Marshall compaction 2.255

69	23	340	190	179	7	85	6.0	2.230	2.285	97.8	100.2	2.4	97.5	99.9	2.4
70	24	340	230	165	9	85	6.0	2.248	2.281	98.6	100.0	1.4	98.3	99.7	1.4
71	25	310	215	180	11	85	6.0	2.209	2.277	96.9	99.9	3.0	96.6	99.5	2.9
72	26	305	228	180	15	85	6.0	2.227	2.289	97.7	100.4	2.7	97.3	100.1	2.8

*Average specific gravity of plant specimens 69 and 71 using 50 blow Marshall compaction 2.280
**Average specific gravity of plant specimens 70 and 72 using 75 blow Marshall compaction 2.288

TABLE III - Average Test Results of Wearing Course Mixture On Concrete Base (Cont.)

Truck No.	Sect No.	Disch Temp, Deg Fahr	Rolling Temp, Deg Fahr 3 Wheel	Pneum	No. of Passes	Contact Press, psi	Per Cent Bitumen	Rdwy Gravity Orig	6-Mon	Per Cent Compaction 50 Blow* Orig	6-Mon	Change	75 Blow** Orig	6-Mon	Change
73	27	340	193	183	7	85	5.8	2.212	2.275	99.0	101.8	2.8	97.6	100.4	2.8
74	28	305	225	193	9	85	5.8	2.242	2.292	100.3	102.6	2.3	98.9	101.1	2.2
75	29	305	188	175	11	85	5.8	2.232	2.295	99.9	102.7	2.8	98.5	101.3	2.8
76	30	310	214	185	15	85	5.8	2.231	2.297	99.8	102.7	2.9	98.5	101.4	2.9

*Average specific gravity of plant specimens 73 and 75 using 50 blow Marshall compaction 2.235
**Average specific gravity of plant specimens 74 and 76 using 75 blow Marshall compaction 2.266

77	31	370	219	192	15	55	6.0	2.204	2.289	97.5	101.2	3.7	95.7	99.4	3.7
78	32	345	233	172	17	55	6.0	2.225	2.280	98.4	100.8	2.4	96.7	99.0	2.3
79	33	330	209	171	19	55	6.0	2.251	2.269	99.6	100.4	0.8	97.8	98.6	0.8

*Average specific gravity of plant specimens 77 and 79 using 50 blow Marshall compaction 2.261
**Average specific gravity of plant specimen 78 using 75 blow Marshall compaction 2.302

80	34	300	225	160	15	55	5.8	2.243	2.287	99.1	101.0	1.9	97.4	99.3	1.9
81	35	295	207	189	17	55	5.8	2.242	2.275	99.1	100.5	1.4	97.4	98.8	1.4
82	36	270	196	172	19	55	5.8	2.236	2.291	98.8	101.3	2.5	97.1	99.5	2.4

*Specific gravity of plant specimen 81 using 50 blow Marshall compaction 2.263
**Average specific gravity of plant specimens 80 and 82 using 75 blow Marshall compaction 2.302

TABLE IV

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

Truck No.	Sect No.	Disch Temp Deg Fahr	Rolling Temp., Deg Fahr		No. of Passes	Contact Press., psi	Per Cent Bitumen	Rdwy Gravity		Per Cent Compaction					
										50 Blow*			75 Blow**		
			3 Wheel	Pneum				Orig	6-Mon	Orig	6-Mon	Change	Orig	6-Mon	Change
10	46	320	-	-	17	75	4.3	2.278	2.314	98.3	99.8	1.5	97.8	99.4	1.6
11	45	315	225	190	15	75	4.3	2.287	2.316	98.7	99.9	1.2	98.2	99.4	1.2
12	44	315	286	213	13	75	4.3	2.323	2.321	100.2	100.1	-0.1	99.7	99.7	0.0
13	43	325	276	204	11	75	4.3	2.298	2.321	99.1	100.1	1.0	98.7	99.7	1.0
14	42	310	252	191	9	75	4.4	2.306	2.322	99.5	100.2	0.7	99.0	99.7	0.7

*Average specific gravity of plant specimens 11 and 13 using 50 blow Marshall compaction 2.318
**Average specific gravity of plant specimens 10, 12 and 14 using 75 blow Marshall compaction 2.329

19	41	335	285	203	17	85	4.3	2.310	2.344	99.1	100.6	1.5	98.7	100.1	1.4
20	40	335	257	200	15	85	4.3	2.298	2.322	98.6	99.6	1.0	98.2	99.2	1.0
21	39	330	249	196	13	85	4.3	2.292	2.327	98.3	99.8	1.5	97.9	99.4	1.5
27	37	320	209	180	11	85	4.3	2.314	2.298	99.3	98.6	-0.7	98.9	98.2	-0.7
25	38	340	266	198	9	85	4.3	2.332	2.308	100.0	99.0	-1.0	99.6	98.6	-1.0

*Average specific gravity of plant specimens 19, 21, 23, 25, 27 and 29 using 50 blow Marshall compaction 2.331
**Average specific gravity of plant specimens 18, 20, 22, 24, 26 and 28 using 75 blow Marshall compaction 2.341

TABLE V

AVERAGE TEST RESULTS OF BINDER COURSE MIXTURE ON CONCRETE BASE

Truck No.	Sect No.	Disch Temp Deg Fahr	Rolling Temp, Deg Fahr		No. of Passes	Contact Press, psi	Per Cent Bitumen	Rdwy Gravity		Per Cent Compaction					
										50 Blow*			75 Blow**		
			3 Wheel	Pneum				Orig	6-Mon	Orig	6-Mon	Change	Orig	6-Mon	Change
30	51	300	217	179	17	85	4.3	2.319	2.343	99.7	100.8	1.1	100.5	101.5	1.0
31	50	320	279	200	15	85	4.3	2.321	2.332	99.8	100.3	0.5	100.6	101.0	0.4
35	47	-	193	173	13	85	4.3	2.316	2.318	99.6	99.7	0.1	100.4	100.4	0.0
34	48	330	216	186	11	85	4.3	2.336	2.324	100.5	100.0	-0.5	101.2	100.7	-0.5
33	49	325	193	170	9	85	4.3	2.313	2.331	99.5	100.3	0.8	100.2	101.0	0.8

*Average specific gravity of plant specimens 31, 33 and 35 using 50 blow Marshall compaction 2.325
**Average specific gravity of plant specimens 30, 32 and 34 using 75 blow Marshall compaction 2.308

36, 39	52,55	310	243	199	17	75	4.3	2.302	2.324	99.0	100.0	1.0	99.1	100.0	0.9
37	53	325	234	198	15	75	4.3	2.323	2.323	99.9	99.9	0.0	100.0	100.0	0.0
40	56	325	226	200	13	75	4.3	2.318	2.333	99.7	100.3	0.6	99.8	100.4	0.6
38, 41	54,57	330	254	195	11	75	4.3	2.307	2.331	99.2	100.3	1.1	99.3	100.3	1.0
42	58	330	242	200	9	75	4.3	2.315	2.335	99.6	100.4	0.8	99.7	100.5	0.8

*Average specific gravity of plant specimens 37, 39 and 41 using 50 blow Marshall compaction 2.325
**Average specific gravity of plant specimens 36, 38, 40 and 42 using 75 blow Marshall compaction 2.323

43, 44, 45	59,60 61	325	213	174	17	55	4.3	2.328	2.341	101.1	101.7	0.6	100.6	101.2	0.6

*Average specific gravity of plant specimens 43 and 45 using 50 blow Marshall compaction 2.302
**Specific gravity of plant specimen 44 using 75 blow Marshall compaction 2.314

specimens are reported in the Appendix. A summary of the field investigation is shown in Tables II through VII. Graphical relationships of these are indicated in Figures 1 through 9.

Tables V and VI in the Appendix show results obtained from the laboratory investigation. They are again shown graphically in Figures 10 through 13.

Discussion of Construction Test Results

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 85 and 75 psi contact pressures, respectively. Average results for these sections are given in Table II. At 75 psi contact pressure (Figure 2), fifteen passes of the pneumatic roller are required to give optimum compaction. Also, the numerical values using 50 blow Marshall compaction is higher than for 75 blow compaction. Furthermore, the shape of the curves indicate that increasing or decreasing the number of passes by one unit decreases the ordinate value by more than one per cent. Six month survey curves shown by dotted lines, indicate that the increase in per cent compaction is quite low at the optimum of fifteen passes as compared to 9, 13, 17 and 19, the former of these showing as much as 1.4 per cent increase for either compactive effort. This further confirms the position of the peaks for the relationships. The relationships obtained using 85 psi contact pressure (Figure 1) indicate that a less number of passes are required to obtain a peak, with any further increase in the

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

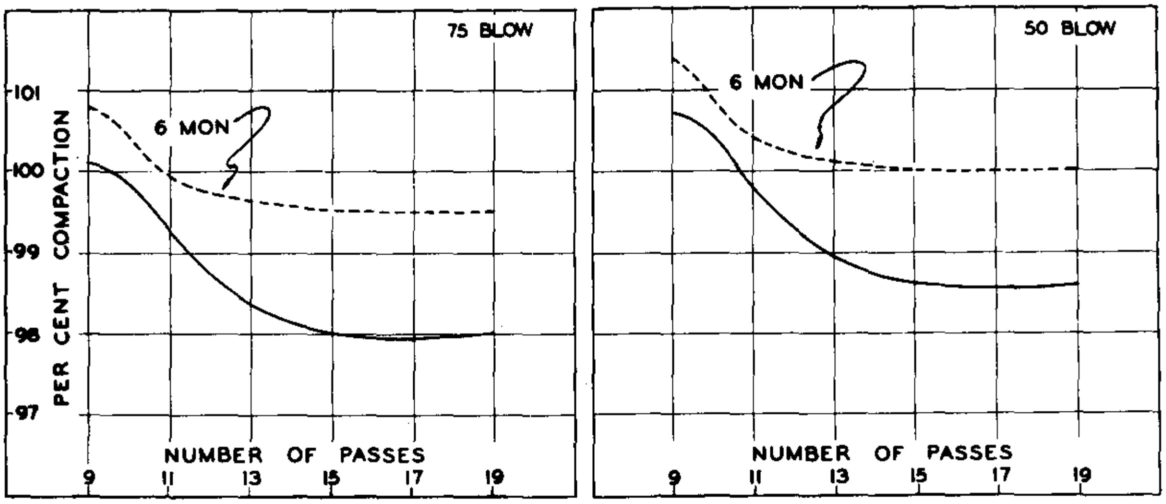

Figure 1 Number of Passes - Per Cent Compaction Relationships at 85 psi Contact Pressure

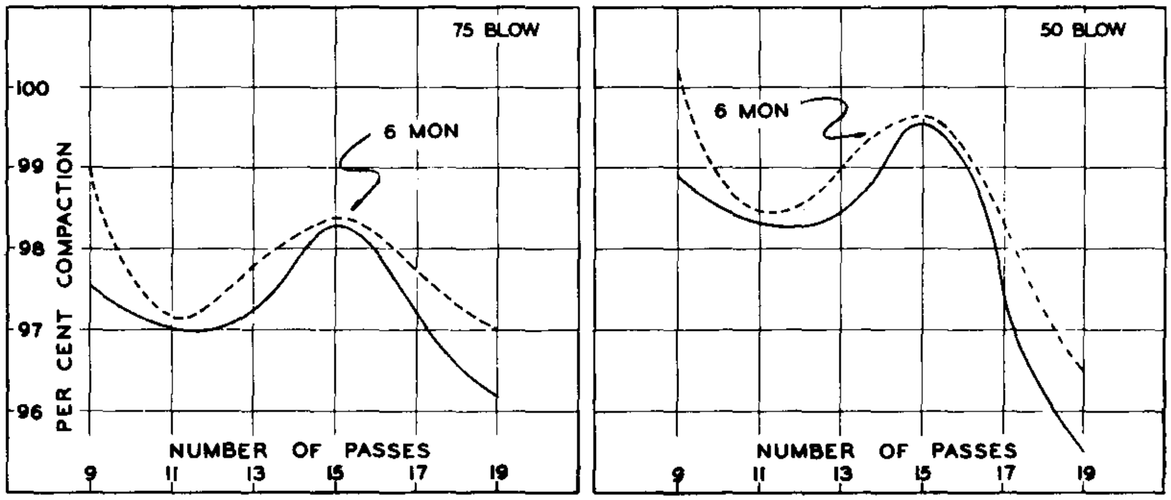

Figure 2 Number of Passes - Per Cent Compaction Relationships at 75 psi Contact Pressure

independent variable reducing the degree of compaction. Here again, as in the previous case, the per cent increase in compaction after six months of traffic is lower at nine passes than at higher efforts; the maximum increase of 1.4% being at 19 passes.

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 the concurrent effect on the densification due to reduction in asphalt content is also shown. Using 6.0% asphalt content and 75 psi contact pressure indicates a not too well defined relationship in that the position of the peak remains undetermined. Results after six months of traffic does not help in locating this position either, since it gives the same per cent compaction at different magnitudes of passes. Furthermore, because of the magnitude of rut measurements, location of this peak remains a matter of conjecture and as such, based on results from the preceding test section, may be placed in the 11 to 13 pass range. Perhaps subsequent periodic surveys may throw some light on this conjecture.

Reduction in asphalt content by 0.2% induces 98.2 and 97.8% of compaction at 17 passes of the pneumatic rollers, using 50 and 75 blow compaction respectively. After six months of traffic, the increase in per cent compaction is the least for this optimum of 17 passes.

At 85 psi contact pressure, Figure 4, nine passes of the

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

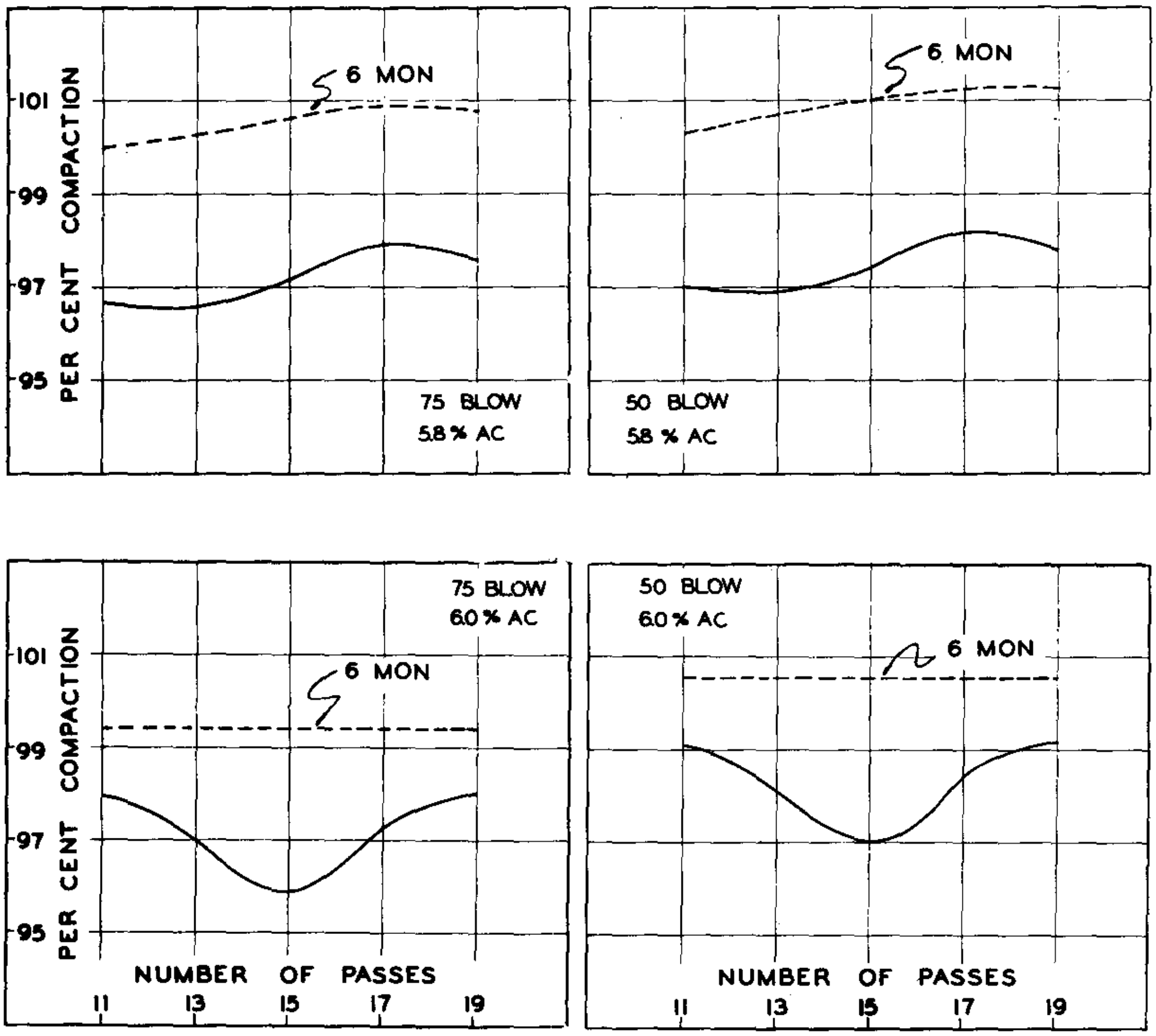

Figure 3 Number of Passes - Per Cent Compaction Relationships

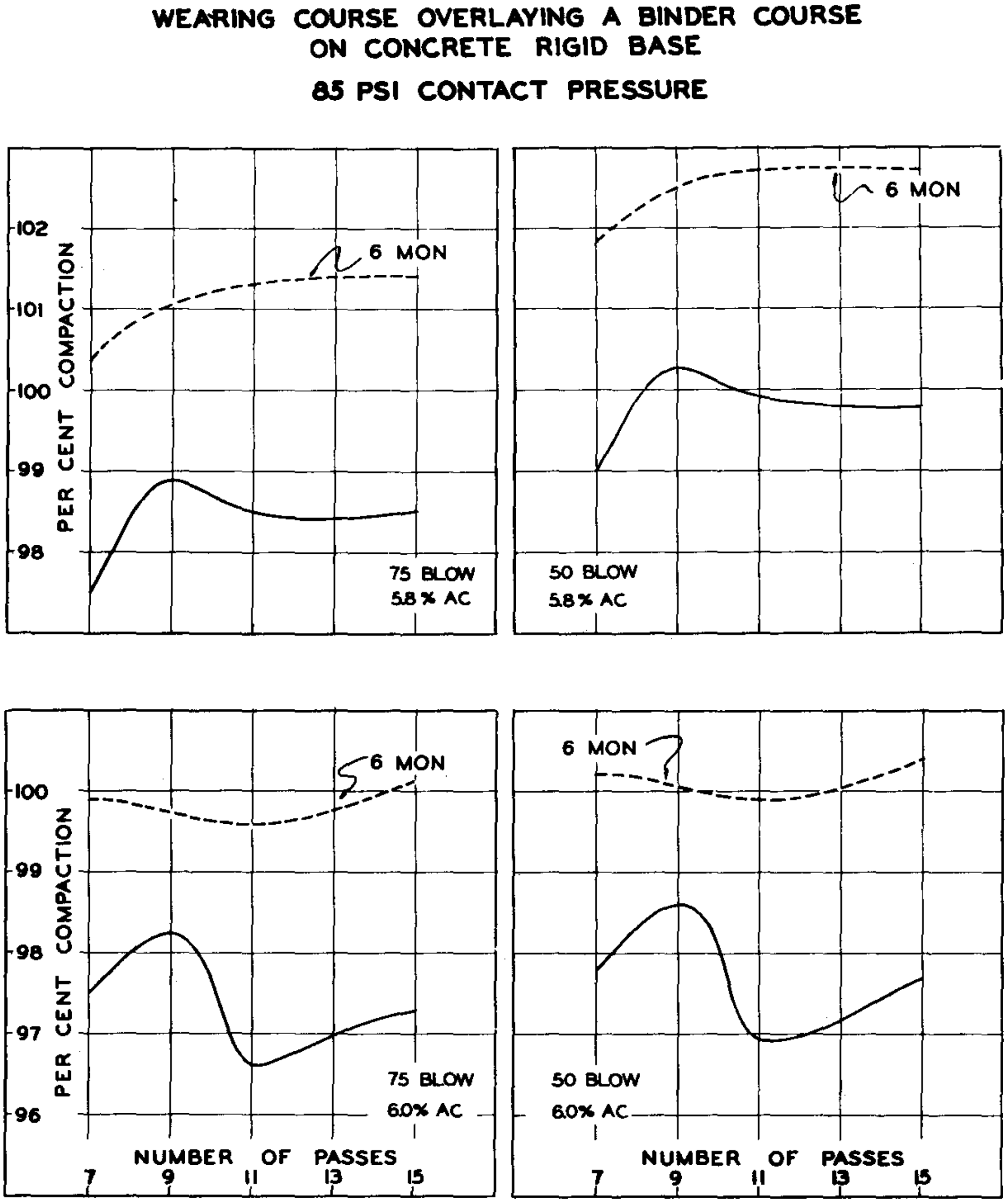

Figure 4 Number of Passes - Per Cent Compaction Relationships

WEARING COURSE OVERLAYING A BINDER COURSE ON CONCRETE RIGID BASE

55 PSI CONTACT PRESSURE

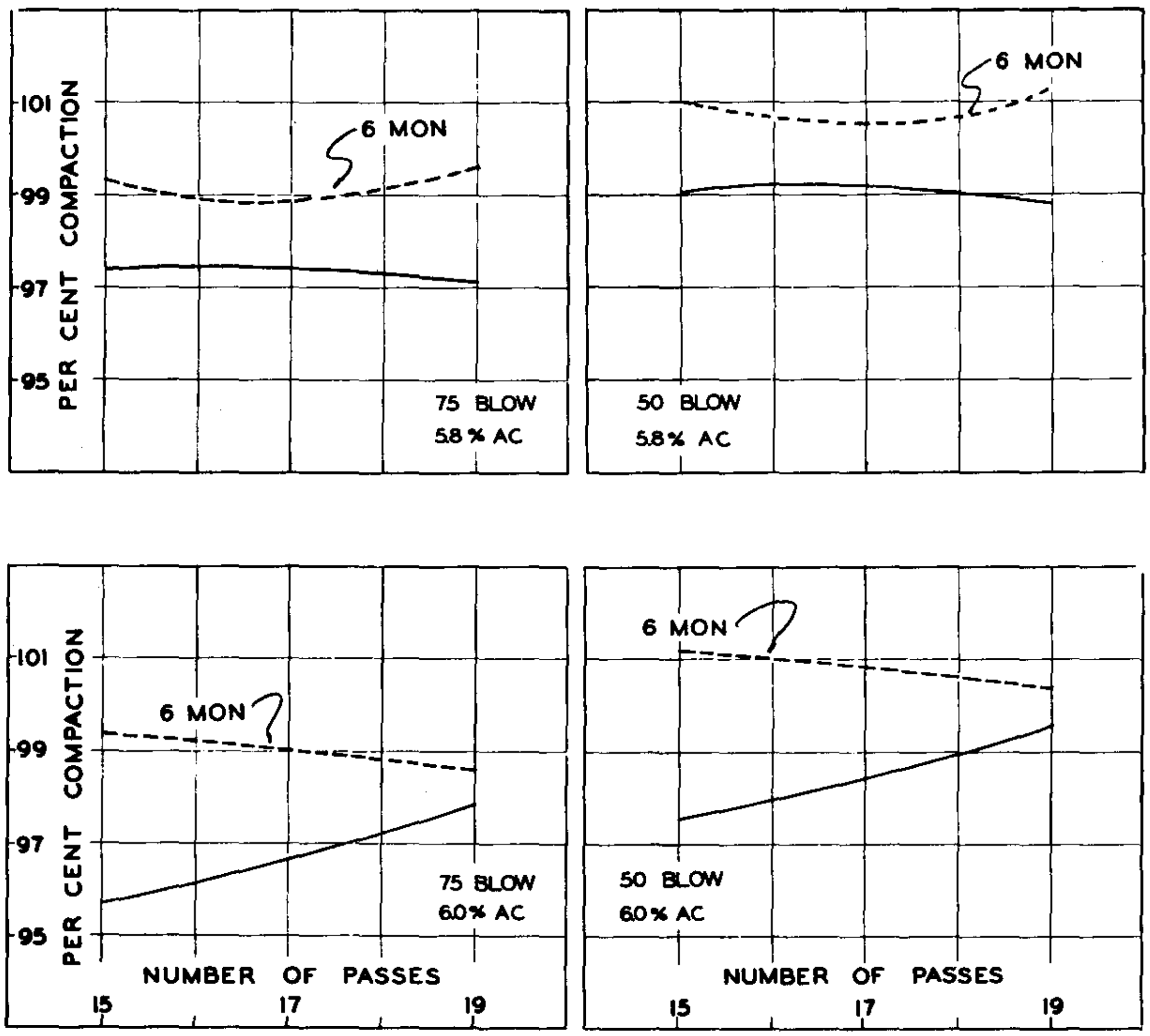

Figure 5 Number of Passes - Per Cent Compaction Relationships

pneumatic rollers gives an optimum of 98.3% at 6.0% asphalt and 98.9% at 5.8% asphalt both for 75 blow compaction. Corresponding values for 50 blow of laboratory compaction are 98.6% and 100.3%. The dotted curve shows the per cent increase in compaction to be least for nine passes of the pneumatic roller.

The relationship for 55 psi contact pressure is illustrated in Figure 5. At 6.0% asphalt using 50 and 75 blow Marshall compaction, 19 passes are required to obtain an optimum of 99.6 and 97.8% respectively. Reduction in asphalt content does not give a very well defined peak, although based on six month results, it could be placed at 17 passes which has the least per cent increase in compaction. Similarly, the minimum per cent increase in compaction is indicated at 19 passes using 6.0% asphalt.

From the preceding three figures, and Table VI, it is seen that,

1. For a given asphalt content, the number of passes required for optimum densification (also maximum numerical values at this optimum) decreases with increasing contact pressure using 75 blow laboratory compaction.
2. Using 50 blow laboratory compaction and optimum asphalt content the number of passes required for optimum condition decreases with increasing contact pressure with lower contact pressure showing maximum numerical value for per cent compaction at the optimum. Corresponding reduction in asphalt content does not show any specific trend.

TABLE VI

PAVEMENT COMPACTION VARIATION DUE TO REDUCTION IN BITUMEN CONTENT FOR DIFFERENT COMPACTIVE EFFORTS

6.0% Bitumen			
Contact Pressure, psi	55	75	85
Number of Passes	19	11	9
Optimum Compaction			
50 - Blow	99.6	99.1	98.6
75 - Blow	97.8	98.0	98.3

5.8% Bitumen			
Contact Pressure, psi	55	75	85
Number of Passes	17	17	9
Optimum Compaction			
50 - Blow	99.1	98.2	100.3
75 - Blow	97.4	97.8	98.9

3. For a given compactive effort and number of passes, reduction in asphalt content from the optimum using 50 and 75 blow laboratory compaction gives higher values for per cent compaction (an increase of 1.7% for 50 blow compaction and 0.6% for 75 blow compaction).

When the above relationships were studied for a binder course mixture, Figures 6 through 9 were obtained. Figure 7 for binder course mixture on surface treatment and flexible base indicate that at a contact pressure of 75 psi, 13 passes are required for optimum condition. Effect of traffic on the densification of this section is the least as shown by the dotted curve, whereas 17 passes show maximum increase in compaction. When the contact pressure is increased to 85 psi, Figure 6 is obtained. Here, nine passes places the peak at 100.0% and 99.6% for 50 and 75 blow compaction respectively. Contrary to all the preceding conditions, the densification after six months of traffic shows a decrease. Usually such a behavior is associated with movement of the mix. Whether such is the case in the present case remains a matter of conjecture. Further periodic surveys may clarify this condition.

When the aforementioned relationships were studied for binder course mixture on rigid base, Figures 8 and 9 were obtained for 75 and 85 psi contact pressures, respectively. At 75 psi pressure 15 passes are required for maximum compaction whereas at 85 psi pressure it takes 11 passes to obtain the optimum. Six months of traffic on sections compacted with 15 passes and 75 psi contact pressure induces no additional

BINDER COURSE ON SURFACE TREATMENT AND FLEXIBLE BASE

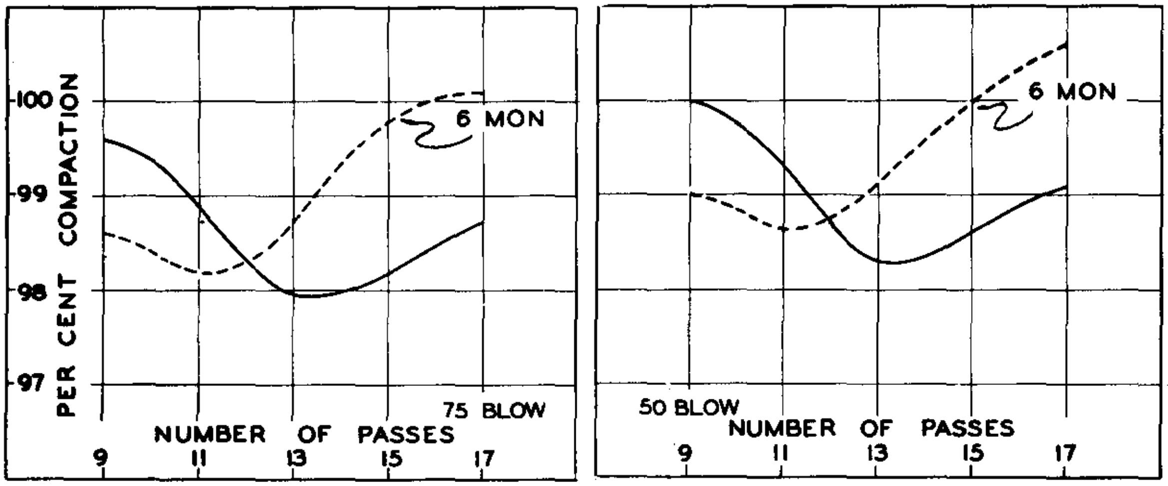

Figure 6 *Relationships of Number of Passes Versus Per Cent Compaction for 85 psi Contact Pressure*

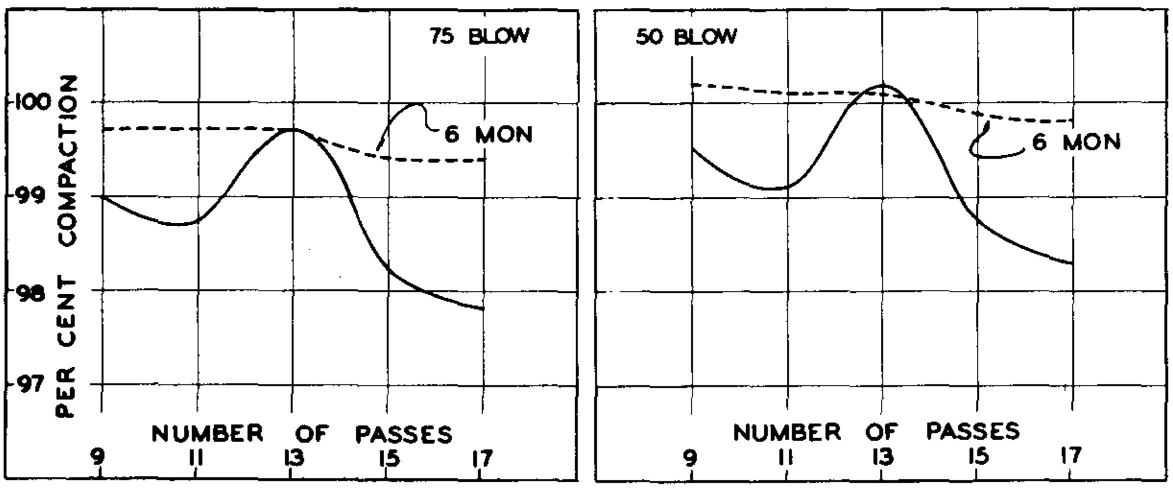

Figure 7 *Relationships of Number of Passes Versus Per Cent Compaction for 75 psi Contact Pressure*

BINDER COURSE ON CONCRETE RIGID BASE

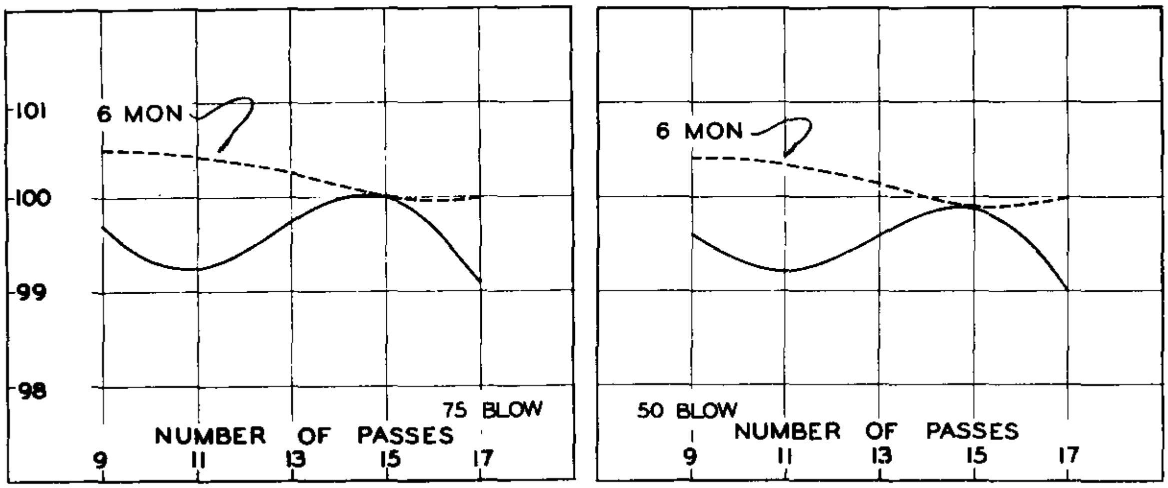

Figure 8 *Number of Passes - Per Cent Compaction Relationships at 75 psi Contact Pressure*

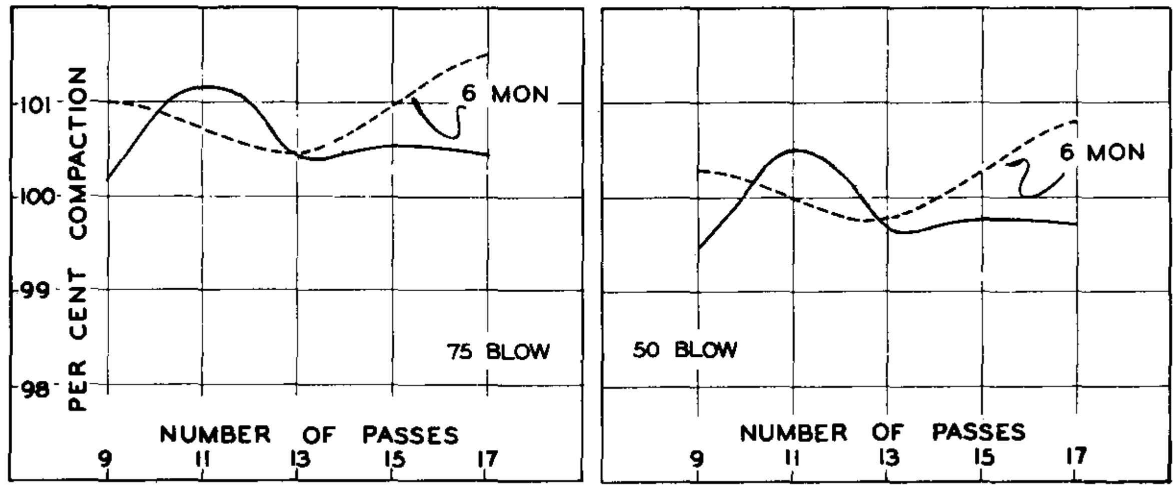

Figure 9 *Number of Passes - Per Cent Compaction Relationships at 85 psi Contact Pressure*

compaction whereas the 85 psi sections with 11 passes show a decrease in the compaction values. Similar behavior was noted in Figure 6. Thus, it is seen that regardless of the base condition, at 85 psi contact pressure, the section giving optimum condition shows a decrease in the compaction value after six months of traffic.

Discussion of Laboratory Investigation

The effect of asphalt content on the density and stability of the asphaltic concrete mixtures using different methods of design and compactive efforts is shown in Figures 10 through 13. Detailed results of the investigation appear in the Appendix.

Figures 10 and 11 for wearing and binder course mixtures respectively, show increase in density with increased compactive effort for the three methods of design with a corresponding decrease in asphalt content. For the gyratory method, three different vertical pressures and gyrations are shown, the latter of which is recorded on charts and shown for each asphalt content on the plot. Looking at the recorded gyratory motion charts, it can be seen that as the asphalt content is increased, there is eventually a point, slightly beyond the peak of the curve at which the band shows a gradual flaring and then more increased flaring for further increase in asphalt(2). This flaring is evidence of flushing of the mixture. These curves further illustrate that varying the number of gyrations has more effect on the density of the mixture than the vertical pressure, provided this pressure does not differ by more than 50 psi.

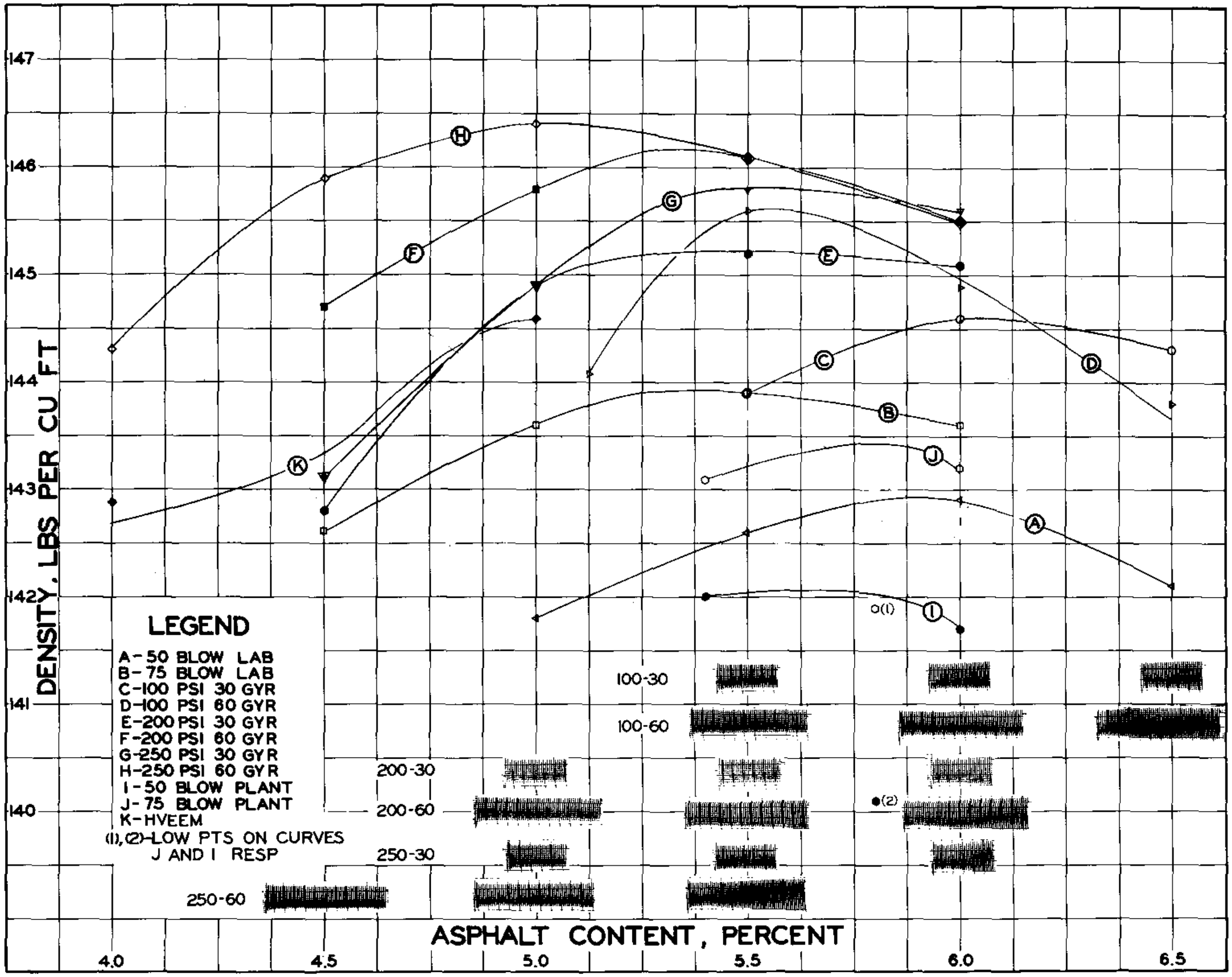

Figure 10 Comparison of Wearing Course Density for Various Types of Laboratory Compaction

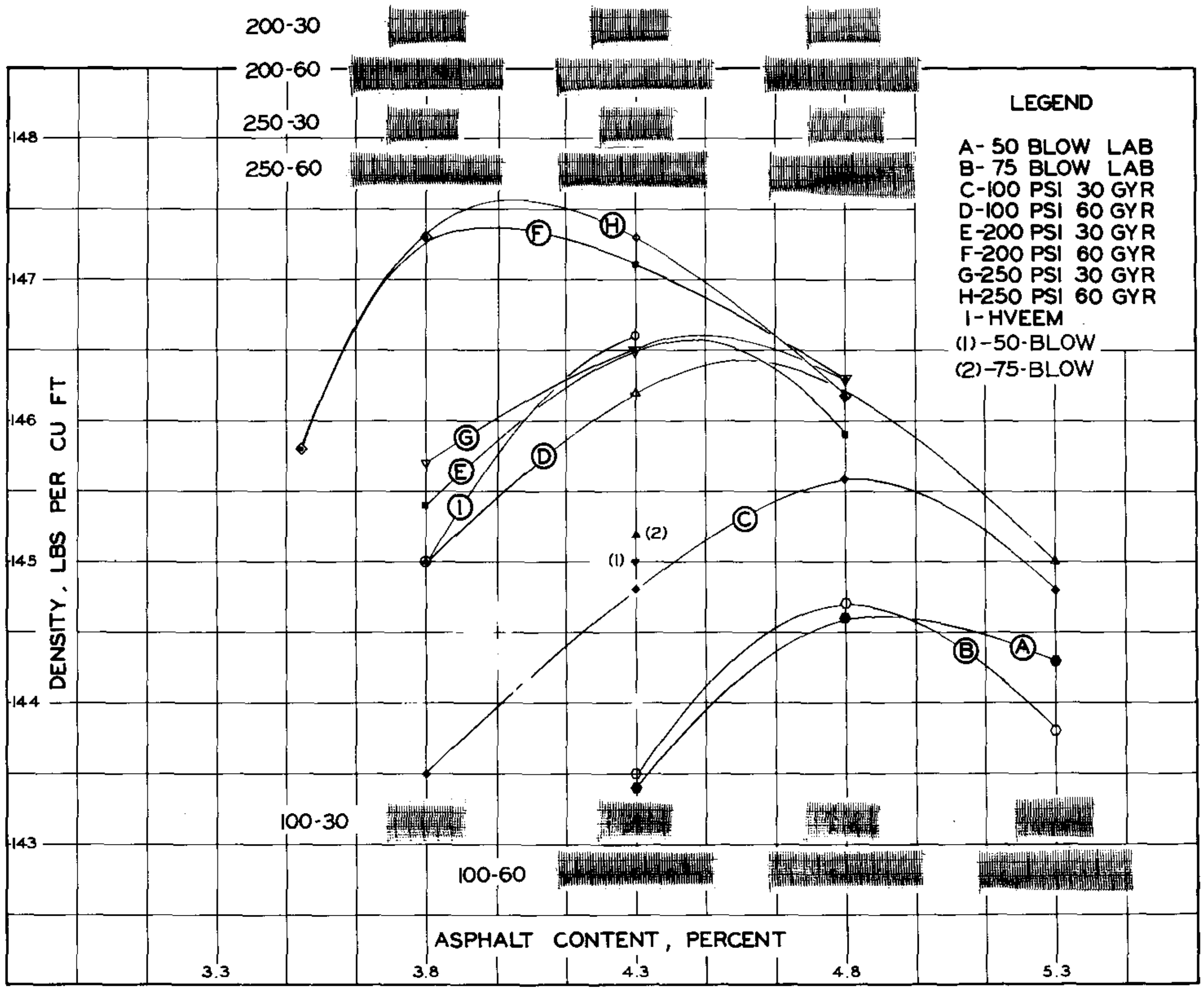

Figure 11 Comparison of Binder Course Density for Various Types of Laboratory Compaction

Fifty and 75 blow Marshall laboratory compaction curves are shown by letters A and B. In both figures, the values shown are below that obtained by the gyratory compaction. For comparison purposes, the 50 and 75 blow plant compaction curves are also shown (I and J in Figure 10 and by points** 5 and 6 in Figure 11). It can be seen that for a wearing course mixture, the laboratory curves show larger values than plant compaction curves. A reverse condition is seen in the case of binder course mixture, Figure 11. Such a contradictory behavior between the two mix types could be attributed to several factors but an attempt to pin point any single factor would be futile.

Laboratory Correlation

Density - The relationships presented in Figures 10 and 11 clearly indicate that no density correlation seems to exist between impact and gyratory kneading compaction at the optimum conditions. In other words, the optimum density by the two methods, although occuring at the same asphalt content, show wide fluctuation in the numerical value (for example, in Figure 10, Curves D, E, F and G and Curve B all show an optimum at 5.5% AC). But on the other hand, comparable values between the two methods at points other than the optimum where the curves cross each other is observed. For instance, the 75 blow laboratory compaction curve in Figure 10 at 5.5% AC which is the optimum, and the 100 psi-30 gyrations gyratory compaction show identical values of 143.9. Also, at 4.5% AC, Curve B and E

** Only one asphalt content was used in binder course mixture.

show close agreement between the density values. Close correlation between 100 psi-30 gyrations and points 5 and 6 (plant results) at 4.3% AC seem to exist in Figure 11 for binder course mix. No agreement between laboratory impact method and the gyratory kneading method is indicated for this particular mix.

Curves K and I in Figures 10 and 11, respectively, by Hveem method, indicate higher densities than the impact method and close to those indicated by Curves E and G at 0.5% less than the optimum asphalt content in Figure 10 and at the optimum in Figure 11.

Stability - Figures 12 and 13 illustrate asphalt content, Marshall stability and compactive effort relationships for impact and gyratory methods of compaction using wearing and binder course mixtures, respectively. The curves in the figures indicate that as the compactive effort is increased, the asphalt content decreases. Curve F (Figure 12) at 200 psi-60 gyrations is equal to Curve H at 250 psi-60 gyrations. Curve D using 100 psi-60 gyrations has approximately the same optimum stability as Curves B and G but at a higher asphalt content.

Furthermore, 75 blow of laboratory impact compaction and Curves E and G, all at the optimum, show values within 100 lbs at 5.0% AC. Likewise, the 50 blow laboratory compaction and Curve C show stabilities within 100 lbs at 5.5% AC, whereas Curves J and C at 6.0% AC show identical stabilities. Results from plant and laboratory for 50 and 75 blow compaction gave poor correlation, with the plant results showing higher values than

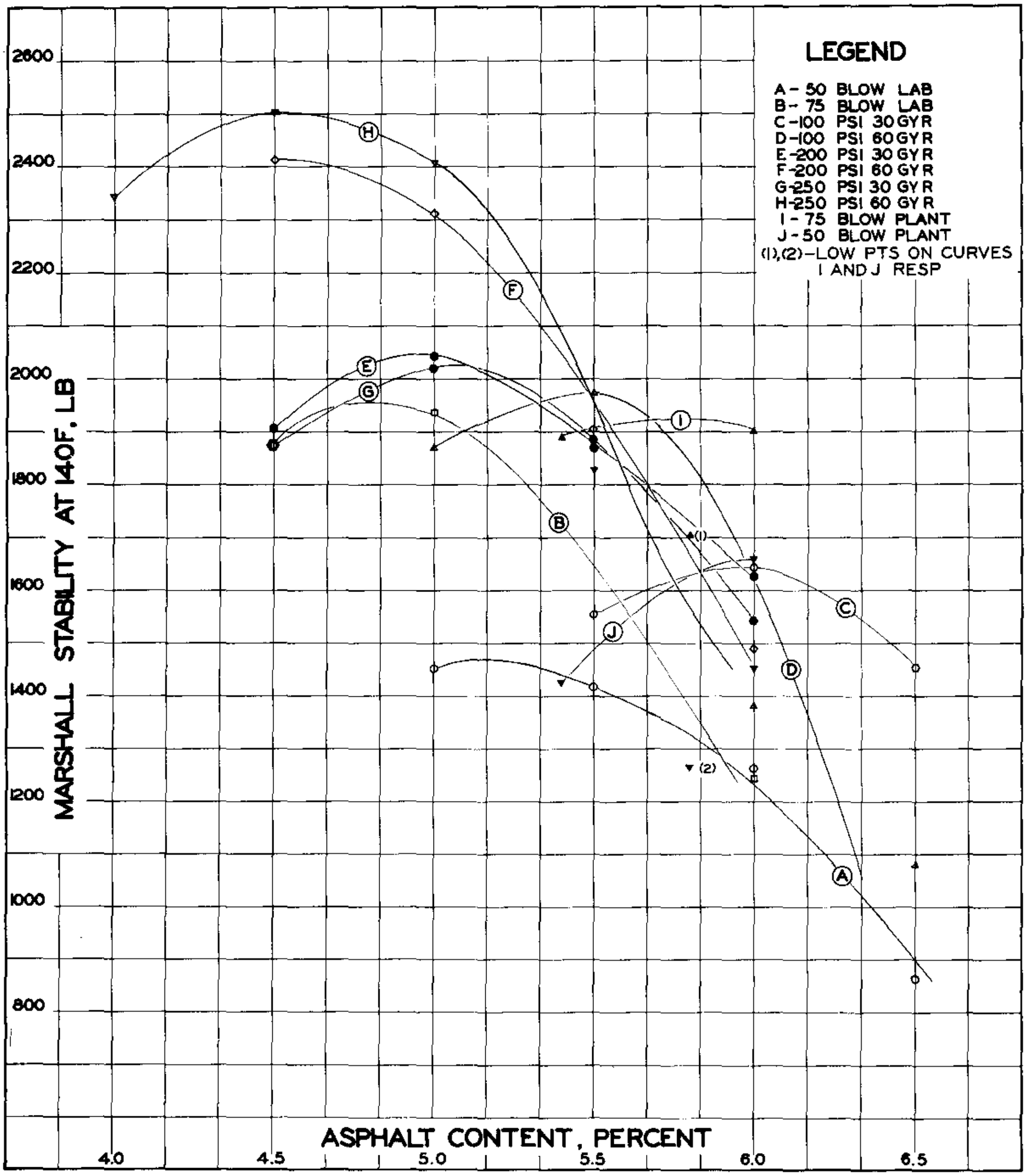

Figure 12 *Comparison of Wearing Course Stability for Various Types of Laboratory Compaction*

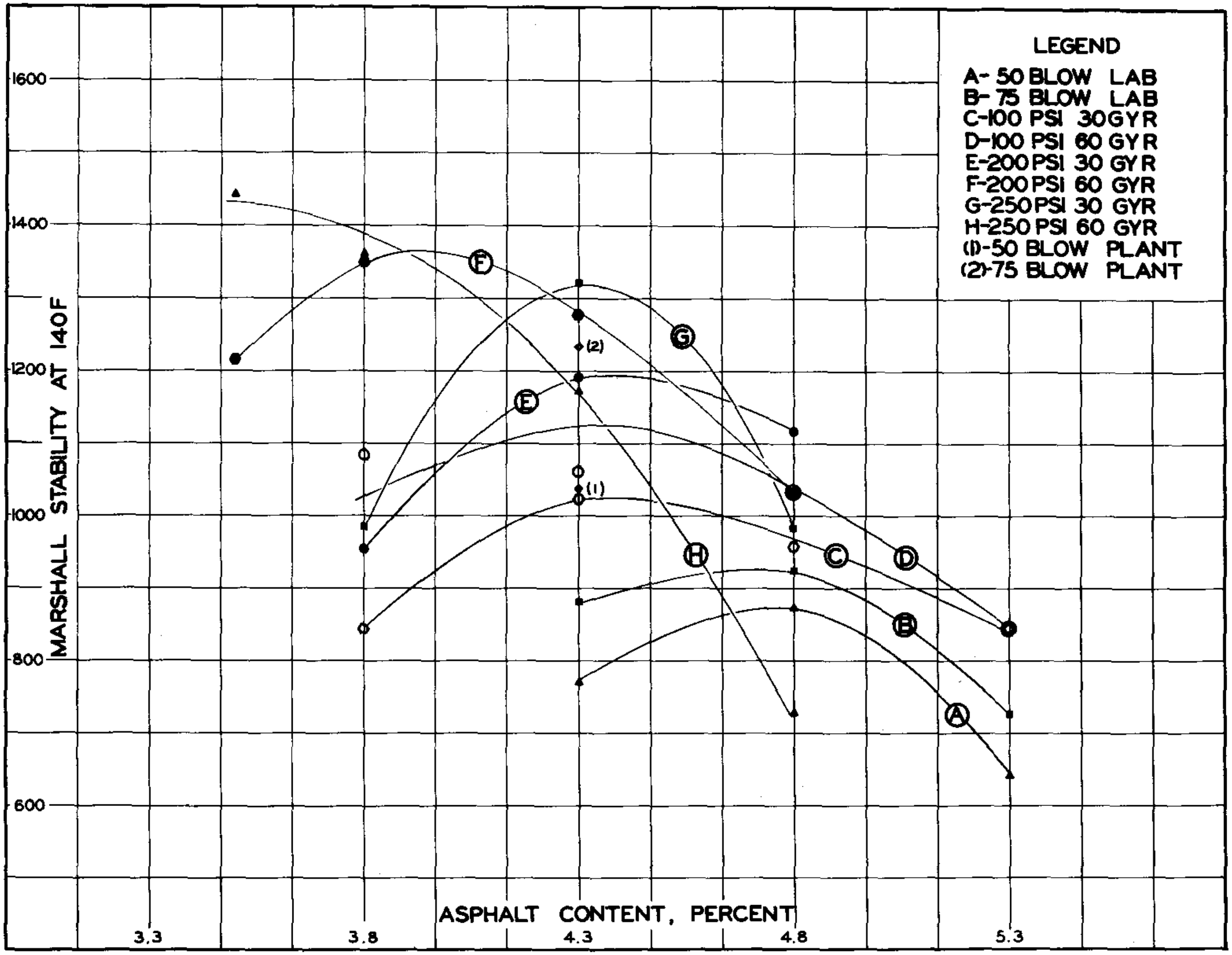

Figure 13 *Comparison of Binder Course Stability for Various Types of Laboratory Compaction*

laboratory results. Quite opposite was the condition observed in Figure 10, Density Correlation.

Figure 13 for binder course mix shows 50 blow plant compaction stability (point 1) equal to Curve C for 100 psi-30 gyrations. The 75 blow compaction optimum stability is likewise equal, within 100 lbs, to Curves E and G at the optimum. Furthermore, the 50 blow compaction represented by point 1 and Curves C and D also show close agreement in stability values within 100 lbs. Here again, as in Figure 12, plant compacted specimens show higher values than laboratory compacted specimens.

The preceding relationships indicate that at optimum conditions for the mixes in question, stability correlation at certain compactive efforts is better than density correlation. Furthermore, 75 blow Marshall compaction gives higher results than 50 blow compaction regardless of the mix type (wearing course or binder course) and method, (laboratory mixing versus plant mixing).

<u>Field and Laboratory Density Correlation</u>

Table VII shows comparison of Marshall compaction results and field compaction results after 6 months of traffic of sections subjected to different compactive efforts. Each field result represents the optimum indicated in Figures 1 through 9. Design density results were likewise obtained from Figures 10 and 11.

It can be seen that the variation in plant and laboratory compacted specimens for 50 blow compaction is more than the

TABLE VII

COMPARISON OF MARSHALL DESIGN DENSITY AND
OPTIMUM FIELD DENSITY AFTER SIX MONTH OF TRAFFIC

Contact Pressure, psi	Course	Optimum No. of Passes	Per Cent Bitumen	Field Density, pcf	Design Density, pcf			
					50-Blow		75-Blow	
					Plant	Lab	Plant	Lab
75	Wearing on	15	5.4	142.4	142.0	142.4	143.1	143.9
85	Surface Treatment	9	5.5	143.7	142.1	142.6	143.2	143.9
55	Wearing on	17	5.8	142.0	141.9	142.9	143.3	143.8
	Concrete Base	19	6.0	141.6	141.7	142.9	143.2	143.6
75	Wearing on	17	5.8	142.1	141.9	142.9	143.3	143.8
	Concrete Base	11	6.0	142.7	141.7	142.9	143.2	143.6
85	Wearing on	9	5.8	143.0	141.9	142.9	143.3	143.8
	Concrete Base	9	6.0	142.3	141.7	142.9	143.2	143.6
75	Binder on Surface Treatment	13	4.3	144.8	145.0	143.4	145.2	143.5
85	Binder on Surface Treatment	9	4.3	144.0				
55	Binder on Concrete Base	17	4.3	146.1				
75	Binder on Concrete Base	15	4.3	145.0				
85	Binder on Concrete Base	11	4.3	145.0				

corresponding variation for 75 blow compaction. Furthermore, based on the average of plant and laboratory results of different compactive efforts, it is seen that the sections compacted at higher pressures have exceeded the 50 blow density whereas none of the sections have exceeded the 75 blow density. The binder course indicates that the lower contact pressure sections show maximum densification which exceeds the average 50 and 75 blow design density. Because of lack of sufficient data on wheel path rutting of these sections, the above statement has to be taken with some reservations. Only upon completion of subsequent periodic surveys can final evaluation of the conditions observed be made. Furthermore, from the construction standpoint, the increased number of passes required by the low contact pressures to attain the desired density may not be desirable.

Variations in Results

Density-Stability - The variation in the test results seemed quite excessive - particularly with respect to plant compacted specimens. Some of the individual test sections with like compactive efforts also showed variations.

The plant compacted binder course specimens showed as much as 23% and 16% variation for Marshall stability and per cent voids for 75 blow compaction respectively. Corresponding variations for 50 blow compaction was 16% and 11%. The wearing course mixture also showed 17% variation in per cent voids for both compactive efforts and 15% and 21% in stability for 50 blow and 75 blow compactive efforts, respectively. The distribution of the results appeared approximately normal for the small number of observations available. Assuming that the variation would recur in the same proportions for large sample populations as for the small ones, a need for improved quality control study seems necessary for establishing cirteria limits and the number of samples necessary to ascertain that these specifications are met. A separate study may be needed because of the vastness of the project.

Temperature - Considerable variation in rolling temperatures was also obtained throughout this study as indicated in Tables II through V. The maximum temperature at which the mix could support the pneumatic roller was 213 F for binder course and 198 F for wearing course mix. Corresponding low temperatures were 173 F and 134 F, respectively. None of the sections however showed any detrimental effects as far as the mix is concerned, such as pickup or other distortion associated with high or low rolling temperatures. Average pneumatic rolling temperature for the mixes at either compactive effort (75 and 85 psi) was 184 F. This is in close agreement with previous findings(3). However, from the information obtained, a need for further study is indicated to investigate the ideal rolling temperature range necessary for optimum compaction at different compactive efforts.

SUMMARY

In the preceding paragraphs an attempt has been made to analyze the effects of the magnitude of the compactive efforts using high intensity pneumatic rollers in the field and correlate this with different methods of compaction in laboratory, the purpose being to equalize the rolling pressures with those obtained under heavy truck traffic. This may help in the production of better nonrutting mixes and further eliminate or at least minimize rutting of asphaltic surfacing. Although no definite conclusions can be drawn at the present time in that periodic observations are to be made over a period of five years, nevertheless, based on field and laboratory data and the six month survey, the following interim conclusions seem warranted:

1. In all cases but one, the numerical values for maximum per cent compaction at 85 psi contact pressure were higher than at 75 psi contact pressure.
2. The 85 psi contact pressure consistently required less rolling coverages for optimum conditions. In the case of wearing course, rolling can be reduced by up to 8 passes (or 4 coverages) when the contact pressure is increased to 85 psi. Similarly, for binder course optimum conditions can be obtained by a reduction of up to 4 passes (2 coverages).
3. The high intensity roller used throughout this project did not show any detrimental effects to the base at any stage of construction.
4. For a given asphalt content, although more compactive effort was required for a binder course mixture on a rigid base than a flexible one, the numerical values for per cent compaction on rigid base was higher than flexible.
5. The densification under traffic was the least after six

months of traffic for sections showing optimum conditions during construction.

6. At this early period in the investigation (six months), no surface irregularities by way of cracking, raveling shoving or rutting were observed.

7. The gyratory and Hveem methods of design gives higher densities (pcf) than the Marshall method.

8. The magnitude of compaction depends primarily on the greater number of gyrations rather than the highest vertical pressure as long as the vertical pressure does not differ by more than 50 psi.

9. Plant mixed wearing course specimens using 50 and 75 blow Marshall compaction show lower density and higher stability values than those mixed in the laboratory at the same asphalt content. The binder course specimens prepared at the plant however, show higher values than laboratory compacted specimens.

10. Six months of traffic has induced density which is equal to or in excess of the design density for 50 blow Marshall compaction. This condition is also observed in a few wearing course sections on concrete base for 75 blow compaction. Such a condition may likely prove detrimental before the expected life of the pavement is reached.

11. Although optimum rolling temperatures were not observed throughout this study, indications are that a rolling temperature of 185 ± 10 F would give satisfactory pavement densities without adversely affecting the pavement mat.

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A P P E N D I X

APPENDIX TABLE I

PLANT RESULTS OF BINDER COURSE MIXTURE

Truck No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of Blows	75	50	75	50	75	50	75	75	50	75	50	75	50	75	50
Specific Gravity	2.293	2.332	2.330	2.332	2.361	2.346	2.354	2.359	2.344	2.338	2.316	2.312	2.320	2.338	2.323
Theoretical Gravity	2.463	2.463	2.463	2.460	2.460	2.460	2.460	2.467	2.462	2.465	2.465	2.465	2.465	2.462	2.462
% Theoretical Gravity	93.1	94.7	94.6	94.8	96.0	95.4	95.7	95.6	95.2	94.9	94.0	93.8	94.1	95.0	94.4
% Voids	6.9	5.3	5.4	5.2	4.0	4.6	4.3	4.4	4.8	5.1	6.0	6.2	5.9	5.0	5.4
Stability @ 140°F, lb.	1245	954	1007	809	1257	1185	1446	1167	1190	1364	1035	667	873	897	1107
Flow, 1/100 Inch	5	5	5	14	7	7	7	6	9	7	9	7	6	8	9

Gradation of the Extracted Aggregate

U. S. Sieve	Per Cent Passing														
1 Inch			100.0		100.0						100.0		100.0		
3/4 Inch			89.7		98.0						85.1		94.2		
1/2 Inch			76.7		81.6						71.6		64.5		
No. 4			49.7		51.7						45.6		41.2		
No. 10			41.7		42.7						38.1		34.3		
No. 40			29.6		28.8						25.8		22.9		
No. 80			10.8		10.7						9.5		7.7		
No. 200			5.1		5.6						5.3		4.4		
Bitumen, %			4.6		4.5						4.1		4.1		

Bin Proportions

Bin 1, %	42.0			42.0				42.0		41.5				41.5	
Bin 2, %	14.0			13.9				14.0		14.5				14.5	
Bin 3, %	24.0			23.9				24.0		24.0				24.0	
Bin 4, %	16.3			16.4				16.3		16.3				16.0	
Mineral Filler, %	3.7			3.8				3.7		3.7				4.0	
Bitumen (80-100), %	4.5			4.6				4.4		4.3				4.4	

Note.- Per cent voids above and in subsequent tables are based on the apparent specific gravity of the aggregate

APPENDIX TABLE I. Plant Results of Binder Course Mixture (Cont.)

Truck No.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
No. of Blows	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75
Specific Gravity	2.334	2.318	2.332	2.326	2.331	2.327	2.315	2.324	2.354	2.340	2.359	2.326	2.354	2.342	2.290
Theoretical Gravity	2.462	2.462	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465
% Theoretical Gravity	94.8	94.2	94.6	94.4	94.6	94.4	93.9	94.3	95.5	94.9	95.7	94.4	95.5	95.0	92.9
% Voids	5.2	5.8	5.4	5.6	5.4	5.6	6.1	5.7	4.5	5.1	4.3	5.6	4.5	5.0	7.1
Stability @ 140°F, lb.	1144	1252	1355	1193	1408	914	1361	1364	1820	943	1750	1355	1573	1225	702
Flow, 1/100 Inch	8	7	9	7	6	8	6	6	7	11	11	6	8	7	11
Gradation of the Extracted Aggregate															
U. S. Sieve	Per Cent Passing														
1 Inch				96.5			96.7			95.3					100.0
3/4 Inch				90.4			89.6			91.2					90.6
1/2 Inch				73.3			72.0			75.8					68.8
No. 4				45.5			47.0			52.9					43.8
No. 10				37.2			38.3			43.4					35.7
No. 40				26.1			27.9			30.6					24.9
No. 80				10.2			11.4			13.0					9.1
No. 200				4.2			4.6			5.9					4.6
Bitumen, %				4.6			4.0			4.8					4.2
Bin Proportions															
Bin 1, %			42.0			42.0			40.0	40.0					40.0
Bin 2, %			17.0			17.0			17.0	17.0					19.0
Bin 3, %			22.0			22.0			24.0	22.0					19.0
Bin 4, %			15.0			15.0			15.0	17.0					17.0
Mineral Filler, %			4.0			4.0			4.0	4.0					4.0
Bitumen (80-100), %			4.3			4.3			4.3	4.3					4.3

APPENDIX TABLE I . Plant Results of Binder Course Mixture (Cont.)

Truck No.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
No. of Blows	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50
Specific Gravity	2.323	2.300	2.329	2.333	2.324	2.321	2.357	2.327	2.304	2.324	2.315	2.320	2.317	2.314	2.288
Theoretical Gravity	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465	2.465
% Theoretical Gravity	94.2	93.3	94.5	94.7	94.3	94.2	95.6	94.4	93.5	94.3	93.9	94.1	94.0	93.9	92.8
% Voids	5.8	6.7	5.5	5.3	5.7	5.8	4.4	5.6	6.5	5.7	6.1	5.9	6.0	6.1	7.2
Stability @ 140°F, lb.	871	834	995	1087	809	975	1152	1298	789	1139	1038	1383	1091	1405	821
Flow, 1/100 Inch	12	13	13	12	11	13	15	12	10	11	11	12	9	6	6
Gradation of the Extracted Aggregate															
U. S. Sieve	Per Cent Passing														
1 Inch				100.0	100.0			100.0				100.0			
3/4 Inch				95.8	96.5			92.5				95.0			
1/2 Inch				76.6	77.5			76.3				75.4			
No. 4				42.7	48.0			42.9				48.8			
No. 10				33.6	38.2			34.4				40.8			
No. 40				23.5	24.6			24.0				27.5			
No. 80				8.6	8.0			8.7				10.4			
No. 200				4.0	4.1			3.6				4.5			
Bitumen, %				4.7	4.3			4.4				4.1			
Bin Proportions															
Bin 1, %	40.0										40.0				
Bin 2, %	19.0										19.0				
Bin 3, %	20.0										20.0				
Bin 4, %	17.0										17.0				
Mineral Filler, %	4.0										4.0				
Bitumen (80-100), %	4.3										4.3				

APPENDIX TABLE II

PLANT RESULTS OF WEARING COURSE MIXTURE

Truck No.	46	47	48	49	50	51	52	53	54	55	56	57
No. of Blows	50	75	50	75	50	75	50	50	75	50	75	50
Specific Gravity	2.310	2.297	2.308	2.322	2.273	2.315	2.304	2.288	2.287	2.248	2.274	2.268
Theoretical Gravity	2.422	2.422	2.451	2.421	2.421	2.421	2.421	2.421	2.421	2.421	2.421	2.421
% Theoretical Gravity	95.4	94.8	94.2	95.9	93.9	95.7	95.2	94.5	94.5	92.9	93.9	93.7
% Voids	4.6	5.2	5.8	4.1	6.1	4.3	4.8	5.5	5.5	7.1	6.1	6.3
Stability @ 140°F, lb.	2208	1875	2765	2712	1518	2118	1750	1519	1326	1184	1692	1242
Flow, 1/100 Inch	8	8	8	6	6	9	9	7	6	9	7	8
Gradation of the Extracted Aggregate												
U. S. Sieve	Per Cent Passing											
1/2 Inch	100.0	97.8	100.0	100.0	99.3	100.0	99.4	99.8	98.9	100.0	100.0	99.4
3/8 Inch	91.7	86.6	95.0	91.8	93.8	92.3	90.8	90.2	92.6	94.1	94.2	95.2
No. 4	65.6	63.1	72.8	63.4	69.8	63.5	59.1	62.9	71.7	71.5	72.1	75.4
No. 10	50.5	49.5	56.3	47.3	53.2	44.5	41.6	46.2	54.5	54.6	53.3	55.0
No. 40	35.0	34.7	39.0	32.9	34.7	28.1	27.5	29.3	32.9	33.3	32.0	33.2
No. 80	14.1	15.6	21.1	17.7	15.7	13.6	15.6	13.9	14.0	13.4	13.6	15.0
No. 200	6.9	7.6	12.5	10.5	8.3	7.2	9.4	7.4	7.3	7.1	6.6	7.4
Bitumen, %	5.0	4.6	5.2	5.1	5.1	5.1	5.4	5.3	5.5	5.3	5.2	5.3
Bin Proportions												
Bin 1, %	45.0		45.0	45.0		43.0		48.0			48.0	
Bin 2, %	31.0		34.0	34.0		35.0		27.0			27.0	
Bin 3, %	19.0		16.0	16.0		17.0		20.0			20.0	
Mineral Filler, %	5.0		5.0	5.0		5.0		5.0			5.0	
Bitumen (80-100), %	4.8		5.0	5.4		5.4		5.4			5.4	

APPENDIX TABLE II. Plant Results of Wearing Course Mixture (Cont.)

Truck No.	58	59	60	61	62	63	64	65	66	67	68	69
No. of Blows	75	50	75	50	75	50	75	50	75	50	75	50
Specific Gravity	2.273	2.283	2.302	2.269	2.306	2.275	2.291	2.238	2.262	2.256	2.248	2.282
Theoretical Gravity	2.421	2.421	2.419	2.399	2.399	2.399	2.399	2.405	2.405	2.405	2.405	2.399
% Theoretical Gravity	93.9	94.3	95.2	94.6	96.1	94.8	95.5	93.1	94.1	93.8	93.5	95.1
% Voids	6.1	5.7	4.8	5.4	3.9	5.2	4.5	6.9	5.9	6.2	6.5	4.9
Stability @ 140°F, lb.	1454	1430	1523	1623	2239	2080	1914	1246	1936	1434	1608	1724
Flow, 1/100 Inch	7	7	7	8	8	8	8	12	8	8	8	8
Gradation of the Extracted Aggregate												
U. S. Sieve	Per Cent Passing											
1/2 Inch	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/8 Inch	95.3	90.3	95.7	92.5	89.0	90.8	93.8	92.3	91.2	92.2	95.6	94.0
No. 4	72.7	67.1	72.9	69.2	65.2	70.0	69.2	71.6	66.6	66.4	70.9	71.4
No. 10	54.9	51.2	55.1	51.0	50.0	51.8	51.3	50.9	48.7	48.3	51.2	54.3
No. 40	33.0	32.3	32.7	31.9	32.0	34.0	34.3	32.9	30.9	30.4	31.2	34.9
No. 80	12.2	12.5	12.2	12.9	13.5	16.8	15.7	17.8	15.5	14.6	14.2	16.6
No. 200	5.6	5.6	5.7	5.6	6.0	9.2	8.2	10.7	5.9	8.7	2.8	9.1
Bitumen, %	5.2	5.2	5.4	5.9	5.8	6.2	5.7	6.0	5.8	5.9	6.1	6.1
Bin Proportions												
Bin 1, %			50.0	48.0				48.0	48.0			48.0
Bin 2, %			27.0	25.0				25.0	25.0			23.0
Bin 3, %			18.0	21.5				21.5	21.5			23.5
Mineral Filler, %			5.0	5.5				5.5	5.5			5.5
Bitumen (80-100), %			5.5	6.0				5.8	5.8			6.0

APPENDIX TABLE II. Plant Results of Wearing Course Mixture (Cont.)

Truck No.	70	71	72	73	74	75	76	77	78	79	80	81	82
No. of Blows	75	50	75	50	75	50	75	50	75	50	75	50	75
Specific Gravity	2.305	2.278	2.270	2.255	2.263	2.215	2.268	2.213	2.302	2.308	2.301	2.263	2.302
Theoretical Gravity	2.399	2.399	2.399	2.405	2.405	2.405	2.405	2.399	2.399	2.399	2.405	2.405	2.405
% Theoretical Gravity	96.1	95.0	94.6	93.8	94.1	92.1	94.3	92.3	96.0	96.2	95.7	94.1	95.7
% Voids	3.9	5.0	5.4	6.2	5.9	7.9	5.7	7.7	4.0	3.8	4.3	5.9	4.3
Stability @ 140°F, lb.	1689	1579	1381	1354	1496	1070	1629	1092	2302	1823	2330	1224	1238
Flow, 1/100 Inch	10	10	10	8	9	7	8	6	9	12	9	6	11
Gradationof the Extracted Aggregate													
U. S. Sieve	Per Cent Passing												
1/2 Inch	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100.0	100.0	100.0		
3/8 Inch	92.3	94.5	94.4	94.6	92.7	92.7	91.2		94.7	96.1	88.0		
No. 4	71.2	72.3	66.9	72.4	68.4	69.4	66.2		70.8	70.8	64.3		
No. 10	55.1	55.6	48.4	52.6	50.4	51.3	49.5		52.6	53.2	48.3		
No. 40	34.7	35.7	31.0	29.9	31.4	31.8	31.3		32.2	34.8	33.2		
No. 80	14.3	15.5	13.3	12.5	14.2	13.4	14.4		15.0	16.3	17.0		
No. 200	8.1	8.3	7.4	7.6	7.3	7.4	8.0		8.5	10.3	9.1		
Bitumen, %	6.2	6.2	5.9	6.0	5.6	5.6	5.6		6.2	6.2	5.8		
Bin Proportions													
Bin 1, %				48.0				48.0			46.0		
Bin 2, %				23.0				23.0			23.0		
Bin 3, %				23.5				23.5			25.5		
Mineral Filler, %				5.5				5.5			5.5		
Bitumen (80-100), %				5.8				6.0			5.8		

APPENDIX TABLE III

DETAILED SPECIFIC GRAVITY RESULTS
ON WEARING COURSE ROADWAY SPECIMENS

Section No.	Specific Gravity									
	Original[1]						6-Month			
	1	2	3	4	5	Average	Rt C/L[2]	C/L	Lt C/L[2]	Average
1	2.276	2.291	2.293			2.287	2.300	2.308	2.301	2.303
2	2.273	2.253	2.279			2.268	2.299	2.290	2.257	2.282
3	2.229	2.227	2.238			2.231	2.294	2.269	2.241	2.268
4	2.249	2.245	2.261			2.252	2.298	2.297	2.260	2.285
5	2.204	2.234	2.240			2.237	2.289	2.271	2.244	2.268
6	2.246	2.245	2.230			2.240	2.299	2.270	2.247	2.272
7	2.250	2.229	2.253			2.244	2.270	2.291	2.279	2.280
8	2.270	2.258	2.264			2.264	2.254	2.311	2.323	2.296
9	2.246	2.247	2.255			2.249	2.235	2.281	2.238	2.251
10	2.260	2.245	2.167[3]			2.253	2.304	2.256	2.241	2.267
11	2.283	2.218[3]	2.277			2.280	2.290	2.274	2.222[3]	2.282
12	2.255	2.248	2.234			2.246	2.273	2.284	2.254	2.270
13	2.200	2.201	2.227			2.209	2.235	2.244	2.206	2.228

(1) From the center line
(2) Average of two specimens
(3) Not used

APPENDIX TABLE III. Detailed Specific Gravity Results on Wearing Course Roadway Specimens (Cont.)

Section No.	Specific Gravity									
	Original(1)						6-Month			
	1	2	3	4	5	Average	Rt C/L(2)	C/L	Lt C/L(2)	Average
14	2.233	2.199	2.255			2.229	2.228	2.246	2.266	2.247
15	2.201	2.196	2.206	2.188	2.197	2.198	2.273	2.264	2.283	2.273
16	2.199	2.208	2.243(3)	2.217	2.198	2.206	2.282	2.273	2.270	2.275
17	2.187	2.184	2.205	2.174	2.193	2.189	2.274	2.263	2.271	2.269
18	2.155	2.187	2.196	2.186	2.178	2.180	2.267	2.245	2.249	2.254
19	2.260	2.238	2.256	2.261	2.254	2.254	2.278	2.289	2.292	2.286
20	2.217	2.233	2.251	2.241	2.244	2.237	2.289	2.282	2.290	2.287
21	2.176	2.208	2.204	2.219	2.211	2.204	2.288	2.285	2.286	2.286
22	2.241	2.253	2.262	2.251	2.218(3)	2.252	2.281	2.281	2.296	2.286
23	2.203	2.220	2.223	2.248	2.255	2.230	2.291	2.285	2.279	2.285
24	2.254	2.262	2.247	2.244	2.232	2.248	2.292	2.280	2.271	2.281
25	2.200	2.205	2.208	2.215	2.216	2.209	2.291	2.275	2.266	2.277
26	2.228	2.230	2.230	2.218	2.231	2.227	2.306	2.278	2.282	2.289
27	2.202	2.207	2.196	2.212	2.245	2.212	2.277	2.269	2.280	2.275

(1) From the center line
(2) Average of two specimens
(3) Not used

APPENDIX TABLE III. Detailed Specific Gravity Results on Wearing Course Roadway Specimens (Cont.)

Section No.	Specific Gravity									
	Original[1]						6-Month			
	1	2	3	4	5	Average	Rt C/L[2]	C/L	Lt C/L[2]	Average
28	2.236	2.255	2.245	2.242	2.232	2.242	2.291	2.293	2.291	2.292
29	2.231	2.227	2.233	2.238	2.229	2.232	2.305	2.292	2.288	2.295
30	2.238	2.248	2.231	2.226	2.210	2.231	2.300	2.289	2.302	2.297
31	2.178	2.183	2.219	2.223	2.218	2.204	2.302	2.276	2.288	2.289
32	2.216	2.221	2.230	2.224	2.218	2.225	2.310	2.269	2.260	2.280
33	2.236	2.243	2.253	2.262	2.262	2.251	2.277	2.287	2.244	2.269
34	2.227	2.255	2.247	2.256	2.229	2.243	2.294	2.282	2.286	2.287
35	2.235	2.234	2.248	2.250	2.241	2.242	2.282	2.278	2.266	2.275
36	2.216	2.249	2.255	2.235	2.227	2.236	2.294	2.288	2.291	2.291

(1) From the center line
(2) Average of two specimens

APPENDIX TABLE IV

DETAILED SPECIFIC GRAVITY RESULTS
ON BINDER COURSE ROADWAY SPECIMENS

Section No.		Specific Gravity							
		Original[1]				6-Month			
		1	2	3	Average	Rt C/L	C/L	Lt C/L	Average
37		2.321	2.306	2.314	2.314	2.317	2.150	2.279	2.298
38	A	2.327	2.308	2.328	2.321	2.287	2.338	2.299	2.308
	B	2.338	2.343	2.347	2.343				
39	A	2.298	2.275	2.309	2.294	2.329	2.336	2.316	2.327
	B	2.277	-	2.303	2.290				
40	A	2.296	2.308	2.274	2.303	2.306	2.335	2.326	2.322
	B	2.295	2.306	2.309	2.293				
41	A	2.322	2.323	2.302	2.303	2.342	2.359	2.332	2.344
	B	2.306	2.309	2.294	2.316				
42	A	2.227[2]	2.297	2.301	2.299	2.321	2.308	2.336	2.322
	B	2.309	2.322	2.308	2.313				
43	A	2.290	-	2.308	2.299	2.308	2.328	2.326	2.321
	B	2.298	2.295	2.295	2.297				
44		2.316	2.317	2.336	2.323	2.322	2.317	2.325	2.321
45		2.285	2.282	2.293	2.287	2.297	2.326	2.324	2.316
46	A	2.273	2.204[2]	2.273	2.273	2.324	2.304	2.315	2.314
	B	2.265	2.272	2.308	2.282				

(1) From the center line
(2) Not used

APPENDIX TABLE IV . Detailed Specific Gravity Results on Binder Course Roadway Specimens (Cont.)

Section No.		Specific Gravity							
		Original[1]				6-Month			
		1	2	3	Average	Rt C/L	C/L	Lt C/L	Average
47	A	2.289	2.309	2.303	2.300	2.307	2.327	2.320	2.318
	B	2.340	2.326	2.326	2.331				
48	A	2.336	2.322	2.327	2.328	2.303	2.329	2.340	2.324
	B	2.339	2.347	2.344	2.343				
49	A	2.327	2.322	2.321	2.323	2.326	2.329	2.337	2.331
	B	2.288	2.315	2.307	2.303				
50		2.300	2.329	2.335	2.321	2.316	2.337	2.344	2.332
51	A	2.335	2.306	2.320	2.320	2.345	2.344	2.341	2.343
	B	2.324	2.307	2.322	2.318				
52		2.306	2.339	2.285	2.310	2.315	2.312	2.322	2.316
53		2.321	2.312	2.336	2.323	2.317	2.322	2.331	2.323
54		2.299	2.276	2.279	2.285	2.309	2.341	2.330	2.327
55		2.283	2.229[2]	2.302	2.293	2.323	2.335	2.336	2.331
56	A	2.305	2.323	2.314	2.314	2.322	2.343	2.335	2.333
	B	2.336	2.313	2.315	2.321				
57		2.326	2.331	2.329	2.329	2.356	2.316	2.332	2.335

(1) From the center line
(2) Not used

APPENDIX TABLE IV. Detailed Specific Gravity Results on Binder Course Roadway Specimens (Cont.)

Section No.	Specific Gravity							
	Original[1]				6-Month			
	1	2	3	Average	Rt C/L	C/L	Lt C/L	Average
58 A	2.329	2.347	2.228[2]	2.338[2]	2.326	2.349	2.330	2.335
B	2.290	2.287	2.297	2.291				
59	2.321	2.337	2.327	2.328	2.315	2.342	2.335	2.331
60	2.330	2.306	2.341	2.326	2.347	2.365	2.329	2.347
61	2.322	2.332	2.337	2.330	2.336	2.352	2.347	2.345

(1) From the center line
(2) Not used

APPENDIX TABLE V

TEST RESULTS OF WEARING COURSE MIX
USING THE MARSHALL, HVEEM AND GYRATORY METHODS

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
50 Blow	5.0	2.265					1337	8
	5.0	2.272					1474	7
	5.0	2.281					1549	9
Average	5.0	2.273	93.2	6.8	62.1	141.8	1453	8
50 Blow	5.5	2.281					1477	9
	5.5	2.283					1322	10
	5.5	2.295					1454	8
Average	5.5	2.286	94.4	5.6	68.8	142.6	1418	9
50 Blow	6.0	2.292					1201	11
	6.0	2.290					1169	12
	6.0	2.288					1422	13
Average	6.0	2.290	95.3	4.7	74.1	142.9	1264	12
50 Blow	6.5	2.275					900	16
	6.5	2.277					790	16
	6.5	2.279					900	18
Average	6.5	2.277	95.4	4.6	75.9	142.1	863	17
75 Blow	4.5	2.289					1976	6
	4.5	2.282					1792	11
	4.5	2.284					1849	6
Average	4.5	2.285	93.0	7.0	59.0	142.6	1872	8

APPENDIX TABLE V. Test Results of Wearing Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
75 Blow	5.0	2.302					1849	8
	5.0	2.305					1959	9
	5.0	2.296					2006	6
Average	5.0	2.301	94.3	5.7	66.4	143.6	1938	8
75 Blow	5.5	2.304					1580	8
	5.5	2.309					1627	13
	5.5	2.304					1517	8
Average	5.5	2.306	95.2	4.8	72.1	143.9	1575	10
75 Blow	6.0	2.301					1217	13
	6.0	2.297					1232	13
	6.0	2.304					1280	13
Average	6.0	2.301	95.8	4.2	76.3	143.6	1243	13
100 PSI 60 Gyrations	5.0	2.314					1785	8
	5.0	2.309					1992	10
	5.0	2.306					1834	8
Average	5.0	2.310	94.7	5.3	68.1	144.1	1870	9
100 PSI 30 Gyrations	5.5	2.302					1375	17
	5.5	2.305					1691	11
	5.5	2.307					1596	8
Average	5.5	2.305	95.2	4.8	72.1	143.9	1554	12

APPENDIX TABLE V. Test Results of Wearing Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
100 PSI								
60 Gyrations	5.5	2.330					1976	10
	5.5	2.334					1991	11
	5.5	2.338					1959	8
Average	5.5	2.334	96.4	3.6	77.8	145.6	1975	9
100 PSI								
30 Gyrations	6.0	2.317					1580	12
	6.0	2.320					1660	12
	6.0	2.313					1691	14
Average	6.0	2.317	96.4	3.6	79.1	144.6	1644	13
100 PSI								
60 Gyrations	6.0	2.324					1422	14
	6.0	2.319					1343	13
Average	6.0	2.322	96.6	3.4	80.1	144.9	1383	14
100 PSI								
30 Gyrations	6.5	2.313					1517	9
	6.5	2.307					1248	16
	6.5	2.317					1596	11
Average	6.5	2.312	96.8	3.2	82.2	144.3	1454	12
100 PSI								
60 Gyrations	6.5	2.301					1043	18
	6.5	2.303					1059	18
	6.5	2.308					1138	24
Average	6.5	2.304	96.5	3.5	80.8	143.8	1080	21

APPENDIX TABLE V. Test Results of Wearing Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
200 PSI								
30 Gyrations	4.5	2.281					1884	8
	4.5	2.290					1929	7
	4.5	2.293					1911	11
Average	4.5	2.288	94.5	5.5	64.7	142.8	1909	9
200 PSI								
60 Gyrations	4.5	2.325					2160	8
	4.5	2.320					2464	8
	4.5	2.312					2622	8
Average	4.5	2.319	94.4	5.6	64.5	144.7	2415	8
200 PSI								
30 Gyrations	5.0	2.324					2006	10
	5.0	2.322					2087	8
	5.0	2.319					2038	11
Average	5.0	2.322	95.2	4.8	70.3	144.9	2044	9
200 PSI								
60 Gyrations	5.0	2.335					2292	11
	5.0	2.336					2339	10
	5.0	2.339					2306	12
Average	5.0	2.337	95.8	4.2	73.2	145.8	2312	11
200 PSI								
30 Gyrations	5.5	2.325					1880	9
	5.5	2.326					1818	14
	5.5	2.330					1911	13
Average	5.5	2.327	96.1	3.9	76.3	145.2	1870	12

APPENDIX TABLE V. Test Results of Wearing Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
200 PSI 60 Gyrations	5.5	2.348					1864	15
	5.5	2.339					2118	8
	5.5	2.337					1729	26
Average	5.5	2.341	96.7	3.3	79.3	146.1	1904	16
200 PSI 30 Gyrations	6.0	2.334					1722	13
	6.0	2.316					1564	14
	6.0	2.329					1596	15
Average	6.0	2.326	96.8	3.2	81.1	145.1	1627	14
200 PSI 60 Gyrations	6.0	2.332					1580	13
	6.0	2.328					1422	14
	6.0	2.335					1481	10
Average	6.0	2.332	97.0	3.0	82.1	145.5	1494	12
250 PSI 30 Gyrations	4.5	2.290					1911	8
	4.5	2.293					1818	7
	4.5	2.297					1896	8
Average	4.5	2.293	93.4	6.6	60.5	143.1	1875	8
250 PSI 60 Gyrations	4.5	2.338					2480	8
	4.5	2.339					2434	5
	4.5	2.338					2592	10
Average	4.5	2.338	95.2	4.8	68.2	145.9	2502	8

APPENDIX TABLE V. Test Results of Wearing Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
250 PSI								
60 Gyrations	5.0	2.349					2470	9
	5.0	2.345					2401	9
	5.0	2.345					2355	7
Average	5.0	2.346	96.2	3.8	75.2	146.4	2409	8
250 PSI								
30 Gyrations	5.0	2.324					2160	11
	5.0	2.321					1834	8
	5.0	2.322					2070	10
Average	5.0	2.322	95.2	4.8	70.3	144.9	2021	10
250 PSI								
60 Gyrations	5.5	2.340					1880	7
	5.5	2.346					1910	11
	5.5	2.339					1691	12
Average	5.5	2.342	96.7	3.3	79.3	146.1	1827	10
250 PSI								
30 Gyrations	5.5	2.332					1959	5
	5.5	2.336					1818	10
	5.5	2.341					1864	9
Average	5.5	2.336	96.4	3.6	77.8	145.8	1880	8
250 PSI								
60 Gyrations	6.0	2.334					1432	14
	6.0	2.327					1406	16
	6.0	2.335					1517	15
Average	6.0	2.332	97.0	3.0	82.1	145.5	1452	15

APPENDIX TABLE V. Test Results of Wearing Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
250 PSI								
30 Gyrations	6.0	2.335					1596	13
	6.0	2.332					1390	13
	6.0	2.333					1643	14
Average	6.0	2.333	97.1	2.9	82.6	145.6	1543	13
250 PSI								
60 Gyrations	4.0	2.319					2449	8
	4.0	2.304					2306	13
	4.0	2.314					2276	8
Average	4.0	2.312	93.4	6.6	57.9	144.3	2344	10
							Cor Stab	Cohesiometer Value
Hveem	4.0	2.30					40	162
	4.0	2.29					38	157
	4.0	2.28					49	239
Average	4.0	2.290	92.5	7.5	54.5	142.9	42	186
Hveem	4.5	2.30					45	277
	4.5	2.29					43	202
	4.5	2.29					43	183
Average	4.5	2.293	93.4	6.6	60.5	143.1	44	221
Hveem	5.0	2.32					36	308
	5.0	2.31					44	236
	5.0	2.32					45	303
Average	5.0	2.317	95.0	5.0	69.4	144.6	42	282

APPENDIX TABLE VI

TEST RESULTS OF BINDER COURSE MIX
USING THE MARSHALL, HVEEM AND GYRATORY METHODS

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
50 Blow	4.3	2.300					775	8
	4.3	2.300					711	6
	4.3	2.293					822	7
Average	4.3	2.298	93.1	6.9	58.4	143.4	769	7
50 Blow	4.8	2.313					837	8
	4.8	2.320					938	8
	4.8	2.321					837	5
Average	4.8	2.318	94.7	5.3	67.3	144.6	871	7
50 Blow	5.3	2.307					711	14
	5.3	2.313					662	14
	5.3	2.316					680	11
Average	5.3	2.312	95.1	4.9	71.0	144.3	684	13
75 Blow	4.3	2.299					995	8
	4.3	2.290					759	7
	4.3	2.311					885	8
Average	4.3	2.300	93.2	6.8	58.8	143.5	880	8
75 Blow	4.8	2.323					980	10
	4.8	2.314					869	9
Average	4.8	2.319	94.8	5.2	67.7	144.7	925	9
75 Blow	5.3	2.299					662	12
	5.3	2.307					632	18
	5.3	2.305					885	16
Average	5.3	2.304	94.8	5.2	69.7	143.8	726	15

APPENDIX TABLE VI. Test Results of Binder Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
100 PSI								
30 Gyrations	3.8	2.295					932	8
	3.8	2.297					743	7
	3.8	2.304					853	7
Average	3.8	2.299	92.4	7.6	53.0	143.5	843	7
100 PSI								
60 Gyrations	3.8	2.333					1280	8
	3.8	2.324					963	7
	3.8	2.316					1011	7
Average	3.8	2.324	93.4	6.6	56.7	145.0	1085	7
100 PSI								
30 Gyrations	4.3	2.314					980	8
	4.3	2.312					995	8
	4.3	2.333					1090	8
Average	4.3	2.320	94.0	6.0	62.0	144.8	1022	8
100 PSI								
60 Gyrations	4.3	2.340					1027	8
	4.3	2.352					1201	9
	4.3	2.338					955	8
Average	4.3	2.343	94.9	5.1	65.9	146.2	1061	8
100 PSI								
30 Gyrations	4.8	2.330					900	11
	4.8	2.335					984	8
	4.8	2.334					984	8
Average	4.8	2.333	95.3	4.7	70.0	145.6	956	9

APPENDIX TABLE VI. Test Results of Binder Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
200 PSI								
60 Gyrations	3.8	2.363					1416	12
	3.8	2.358					1283	10
	3.8	2.361					1350	11
Average	3.8	2.361	94.9	5.1	63.8	147.3	1350	11
200 PSI								
30 Gyrations	4.3	2.347					1317	7
	4.3	2.347					971	9
	4.3	2.348					1283	10
Average	4.3	2.347	95.1	4.9	66.9	146.5	1190	9
200 PSI								
60 Gyrations	4.3	2.359					1283	13
	4.3	2.346					1086	9
	4.3	2.365					1464	10
Average	4.3	2.357	95.5	4.5	68.8	147.1	1278	11
200 PSI								
30 Gyrations	4.8	2.329					1232	14
	4.8	2.353					1086	7
	4.8	2.332					1027	11
Average	4.8	2.338	95.5	4.5	71.0	145.9	1115	11
200 PSI								
60 Gyrations	4.8	2.339					1135	13
	4.8	2.344					938	11
	4.8	2.353					1021	11
Average	4.8	2.345	95.8	4.2	72.4	146.3	1031	12

APPENDIX TABLE VI. Test Results of Binder Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	Per Cent V F A	Density Lbs/Cu Ft	Stab	Flow
100 PSI								
60 Gyrations	4.8	2.345					1021	12
	4.8	2.335					1058	7
	4.8	2.349					1021	9
Average	4.8	2.343	95.7	4.3	72.0	146.2	1033	9
100 PSI								
30 Gyrations	5.3	2.324					922	10
	5.3	2.322					774	15
	5.3	2.315					837	16
Average	5.3	2.320	95.5	4.5	72.8	144.8	844	14
100 PSI								
60 Gyrations	5.3	2.322					889	16
	5.3	2.330					869	15
	5.3	2.321					774	16
Average	5.3	2.324	95.6	4.4	73.3	145.0	844	16
200 PSI								
60 Gyrations	3.5	2.329					1138	7
	3.5	2.339					1169	7
	3.5	2.340					1350	7
Average	3.5	2.336	93.6	6.4	55.6	145.8	1219	7
200 PSI								
30 Gyrations	3.8	2.338					885	7
	3.8	2.327					980	7
	3.8	2.326					995	8
Average	3.8	2.330	93.7	6.3	57.9	145.4	953	8

APPENDIX TABLE VI. Test Results of Binder Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	Theo Gr	Voids	V F A	Lbs/Cu Ft	Stab	Flow
250 PSI								
60 Gyrations	3.5	2.319					1311	7
	3.5	2.347					1485	7
	3.5	2.345					1530	7
Average	3.5	2.336	93.6	6.4	55.6	145.8	1442	7
250 PSI								
60 Gyrations	3.8	2.372					1365	10
	3.8	2.362					1317	8
	3.8	2.345					1382	6
Average	3.8	2.360	94.9	5.1	63.3	147.3	1355	8
250 PSI								
30 Gyrations	3.8	2.335					945	8
	3.8	2.328					1027	10
	3.8	2.342					980	7
Average	3.8	2.335	93.9	6.1	58.8	145.7	984	8
250 PSI								
60 Gyrations	4.3	2.356					1135	8
	4.3	2.365					1070	11
	4.3	2.363					1317	10
Average	4.3	2.361	95.6	4.4	69.3	147.3	1174	10
250 PSI								
30 Gyrations	4.3							7
	4.3	2.348					1497	8
	4.3	2.345					1152	8
Average	4.3	2.347	95.2	4.8	69.1	146.5	1325	8

APPENDIX TABLE VI. Test Results of Binder Course Mix Using the Marshall, Hveem and Gyratory Methods (Cont.)

Comp Effort	% A C	Sp Gr	% Theo Gr	Per Cent Voids	V F A	Density Lbs/Cu Ft	Stab	Flow
250 PSI								
60 Gyrations	4.8	2.351					643	15
	4.8	2.339					823	13
	4.8	2.339					724	13
Average	4.8	2.343	95.7	4.3	72.0	146.2	730	14
250 PSI								
30 Gyrations	4.8	2.347					922	7
	4.8	2.344					938	11
	4.8	2.342					1086	13
Average	4.8	2.344	95.8	4.2	72.4	146.3	982	10
							Cor Stab	Cohesiometer Value
Hveem	3.8	2.32					29	145
	3.8	2.31					37	124
	3.8	2.34					35	165
Average	3.8	2.323	93.4	6.6	56.7	145.0	34	145
Hveem	4.3	2.35					22	208
	4.3	2.35					28	185
	4.3	2.35					23	205
Average	4.3	2.350	95.2	4.8	67.4	146.6	24	199