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It was determined that adequate densities were not being obtained with the California Standard Specifications and new Standard Special Provisions were written. A rolling procedure was developed for both thick-lift and thin-lift construction.

Measurements were made of recently constructed pavements to determine the riding qualities associated with the various construction methods using different lift thicknesses. Standard Special Provisions were written to improve the final surface roughness by limiting the lift thicknesses.

Research was also conducted on the use of nuclear gages to determine asphalt concrete densities and a method was written for the use of nuclear gages in conjunction with the qualification of rollers.

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Asphalt concrete, compaction, nuclear gages, pneumatic rollers, vibratory rollers, amplitude, frequency, temperature, riding quality

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HIGHWAY RESEARCH REPORT

COMPACTION OF ASPHALT CONCRETE PAVEMENTS

FINAL REPORT

74-09

STATE OF CALIFORNIA	TRANSPORTATION LABORATORY
BUSINESS AND TRANSPORTATION AGENCY	RESEARCH REPORT
DEPARTMENT OF TRANSPORTATION	CA-DOT-TL-3294-4-74-09
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DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
TRANSPORTATION LABORATORY
5900 FOLSOM BLVD., SACRAMENTO 95819

February 1974

CA-DOT-TL-3294-4-74-09
FHWA No. D-05-26

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is a final research report titled:

COMPACTION OF ASPHALT CONCRETE PAVEMENTS

By

James A. Cechetini
Co-Principal Investigator

George B. Sherman
Principal Investigator

Very truly yours,

JOHN L. BEATON
Chief, Transportation Laboratory

Attachment

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the construction personnel of the various districts of the State of California Department of Transportation and of several California cities for their cooperation in obtaining the data for this investigation.

This is the final report for a study of the compaction of asphalt concrete pavement. This work was performed in cooperation with the U. S. Department of Transportation, Federal Highway Administration (Federal Program No. HPR-1(5), D-05-26).

TABLE OF CONTENTS

INTRODUCTION

The problems of compacting asphalt concrete pavements are as prevalent today as they were twenty years ago. In many instances, the same rolling sequence as well as the same rolling equipment is still being used. This is true even though the production of hot plants and the speed of pavers have increased immensely. Only in recent years has the paving engineer seen the introduction of new equipment for use in the compaction phase of the construction process.

Many requirements for compaction equipment are either restrictive or obsolete, yet the contractors may not deviate from these requirements. Therefore, this research project was initiated in order to study spreading and compaction of asphalt concrete pavements. The specific objectives were:

1. To determine if a rapid method can be used to determine relative compaction of asphalt concrete pavements immediately following the final rolling;

2. To determine if adequate asphalt concrete pavement compaction was being obtained when the procedure required by the California Standard Specifications was being used;

3. To establish rolling procedures for both thick-lift and thin-lift construction to assure adequate compaction, and

4. To determine if the riding quality of the highways would be adversely affected by thick-lift construction.

The term "adequate density" as used in this study is defined as a relative compaction of 95 percent. Relative compaction is the ratio of the in-place density of the asphalt concrete pavement to the test maximum density of the same asphalt concrete mix when compacted in accordance with Test Method No. Calif. 304F (ASTM D1561-71).

Three interim reports have been written for this project in addition to this final report.

The first report, titled "Asphalt Concrete Compaction Studies Using Nuclear Devices", was published in March 1967[1]. This report contains a discussion of the development of a procedure for determining asphalt concrete densities that incorporates the use of nuclear gages.

The second interim report, titled "Compaction of Thick Lift Asphalt Concrete Pavements"[2], was published in December 1968. This report covered the compaction equipment studies up to that date. An investigation of thick lift pavements was also included.

The third interim report, titled "Vibratory Compaction of Asphalt Concrete Pavements", was written in 1973[3]. This report presented the findings to date on several different vibratory rollers and contained a discussion of 1) the effect of vibratory compaction on asphalt and fine aggregate distribution within the asphalt concrete lift and 2) asphalt concrete water permeability.

CONCLUSIONS

The following conclusions, some of which are presented in the previously published interim reports for this project, are applicable to asphalt concrete paving operations commonly found in California.

Static Compactors

1. Compliance with the asphalt concrete compaction procedure required by the 1973 California Standard Specifications will not insure the desired 95 percent relative compaction;

2. Increasing the number of coverages during the breakdown operation from one to three will generally provide 95 percent relative compaction providing the temperature parameters are met. Further studies should be made to verify this.

Pneumatic Compactors

1. The use of heavy pneumatics for breakdown rolling will not result in a final relative compaction of at least 95 percent when asphalt concrete mixes, compaction temperatures, and intermediate and final compaction procedures of the type studied are used;

2. No advantage with respect to density will be obtained by varying the tire pressure on pneumatic rollers from 30 to 120 psi. The optimum tire pressure is about 90 psi.

Vibratory Compactors

1. There are several models of vibratory rollers that can provide 95 percent relative compaction per California Division of Highways procedures;

2. Vibratory compaction decreases pavement water permeability as much as or more than pneumatic rolling;

3. Generally, the most economical procedure for obtaining a relative compaction of 95 percent or higher is to use an approved vibratory roller because intermediate rolling with a pneumatic roller will not be required (per preceding conclusion number 2).

4. Vibratory rollers may cause migration of asphalt coated fines to the surface;

5. There is no one combination of roller frequency, amplitude, speed, and weight that will assure the realization of maximum pavement density for all materials or for all lift thicknesses;

6. In this study, vibratory rollers operating at frequencies lower than 1700 VPM normally left undulations giving the surface a "wash-board" appearance. No undulations were noted on sections compacted by vibratory rollers operating at a frequency above 1800 VPM;

7. Double vibratory drum rollers tested to date have attained higher densities per coverage than other types, and

8. Vibratory rollers using pneumatic drive wheels were judged unsatisfactory due to "pick-up", appearance of the pavement, and/or their failure to obtain 95 percent relative compaction.

Nuclear Gages

1. Nuclear gages can be used to adequately determine asphalt concrete pavement densities;

2. Use of nuclear gages in the backscatter mode is the most practical method of measuring asphalt concrete pavement densities.

Thick-Lift Pavements

1. Pavements constructed with thick lifts (0.3' or thicker) can be placed without sacrificing density;

2. An acceptable profile index can be obtained on thick-lift asphalt concrete pavements provided a 0.25 foot (maximum) thick leveling course is placed prior to placing the 0.20 foot (maximum) thick surface lift. Further investigation should be made to verify this.

IMPLEMENTATION

The results of this study have been implemented via California Standard Special Provisions 39.01, 39.02, 39.03, and 39.04 for asphalt concrete (Appendix A), and Method No. Calif. 913 (Appendix B) for evaluating the compaction capabilities of asphalt concrete compactors. The results of this study will also be used as the basis for trial use of end-point asphalt concrete compaction specifications.

DISCUSSION

General

To study the asphalt concrete compaction problem, several physical measurements were made on each project to evaluate the procedures being tried. These included:

a. Compaction, as measured using nuclear gages;

b. Temperature of the AC mix when delivered to the street;

c. The speed of the paver;

d. The type, weight, and number of coverages* of the various rollers used during each rolling phase, and

e. The temperature of the AC mat (at mid-depth) during the breakdown, intermediate, and final rolling procedure.

Asphalt concrete samples were taken from behind the paver, then later compacted in the laboratory for maximum laboratory density determinations. Density measurements via nuclear gage were made immediately behind the paver and after each successive coverage by the various compactors. A density survey was also made of the entire test section at randomly selected locations after the compaction operation had been completed.

Rapid Determination of Asphalt Concrete Pavement Density

The first objective of this study was to determine if a rapid method could be used to determine asphalt concrete pavement density immediately following the final rolling. A report prepared in March 1967 titled "Asphalt Concrete Compaction Studies Using Nuclear Devices" [1] contains a description of the findings for this phase of the project.

It was determined that heat-shielded nuclear gages capable of withstanding temperatures of up to 350°F would be necessary. Tests were conducted by both the direct transmission and backscatter techniques. Although studies have shown that the direct transmission method may be more accurate for thick sections than the backscatter technique, it has since been determined that the backscatter technique is the more practical overall method for asphalt concrete pavements.

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*A coverage was as many movements of the roller in either direction in a single path, as was necessary to cover the entire paving width.

A summary of the tests conducted during the evaluation of the nuclear gages by the backscatter technique is shown in Table 1. A number of cores were taken for density determination at the exact location where the readings were obtained with the nuclear gage. The results of the two methods compare very well.

The test method incorporating the nuclear gage for evaluating compactors is shown in the Appendix B as Method No. Calif. 913.

Study of "Present" Rolling Procedure

The second objective was to determine if compliance with the then current California rolling specifications was producing adequate asphalt concrete pavement densities. Test sections were constructed throughout California with the majority of these test sections being an integral part of a mainline freeway. The data collected from the tests clearly indicated that the required rolling sequence of one coverage by a 12-ton tandem followed by three coverages by a pneumatic and one coverage by an 8-ton tandem did not consistently produce an acceptable density. However, by increasing the number of coverages during the breakdown operation to six, a significant increase in density was noticed. Because there has to be some reasonable balance between the number of coverages and economics, and because most of the compaction is achieved during the first 3 passes, an increase from one breakdown coverage to three breakdown coverages has subsequently been incorporated into California's Standard Special Provisions. The results of the study to determine the effect of increasing the number of coverages are presented in Table 2. They have been summarized as follows:

a. Those pavements receiving two breakdown coverages followed by various combinations of intermediate and final rolling had an average final relative compaction of 91 percent with a range of 88 to 97 percent.

b. Those receiving four breakdown coverages prior to the intermediate and final rolling had an average final relative compaction of 93 percent with a range of 88 to 97 percent.

c. Those receiving six breakdown coverages prior to the intermediate and final rolling had an average final relative compaction of 94 percent with a range of 91 to 99 percent.

Although several combinations of intermediate and final rolling were tried with two, four and six breakdown coverages, experience has indicated that the final density is influenced considerably more by the breakdown rolling than by the intermediate and final rolling. Consequently, the differences noted in final compaction have been attributed to the number of breakdown coverages used. On some of the projects, as discussed in the second interim report[2], a vibratory plate was used in conjunction with, or directly behind, the paver with no apparent benefit.

Thick-Lift and Thin-Lift Rolling Procedures

A. Static Compactors

The third objective was to try to establish rolling procedures for both thick-lift and thin-lift construction which will assure adequate density.

As stated previously, the rolling procedure required by the California Standard Specifications was found to be inadequate for both thick-lift and thin-lift sections.

The results of this study indicated that by increasing the number of coverages during breakdown for both thick and thin lifts, relative compaction could be significantly increased. Also, in addition to establishing a procedure for the use of static rollers, the use of pneumatic and vibratory rollers was investigated.

B. Pneumatic Compactors

During the time this study was in progress, papers by Minor[4], Rensel[5], and LeClerc[6] were presented on the use of heavy pneumatic rollers for breakdown rolling. Their findings indicated that the use of these rollers would result in higher densities than that attained when using normal rolling equipment.

Six pneumatically rolled test sections were therefore constructed on California projects and, contrary to the findings of these other researchers, the use of the pneumatic compactors (14 to 16 tons, 30 to 120 psi) for breakdown rolling offered no particular advantages even though as many as sixteen coverages were applied. In fact, the best relative compaction (final) achieved using pneumatic rollers for breakdown was 93 percent (See Table 3). On one of these test sections, a 16-ton "air-on-the-run" pneumatic roller (Bros) was used for the breakdown operation. Very little improvement in density was shown after the first coverage of the pneumatic compactor. The tire pressure was then progressively increased to 120 psi. When the 120 psi pressure was used, the wheels broke through the compacted mat and decompacted approximately the top 1-inch. On this job, one coverage by an 8-ton tandem roller significantly increased the density even though the pavement had previously received sixteen coverages by the pneumatic compactor (See Figure 1, next page). Also, subsequent experience has indicated that the "air-on-the-run" approach may not be satisfactory for all intervals and under all conditions. The main objections have been:

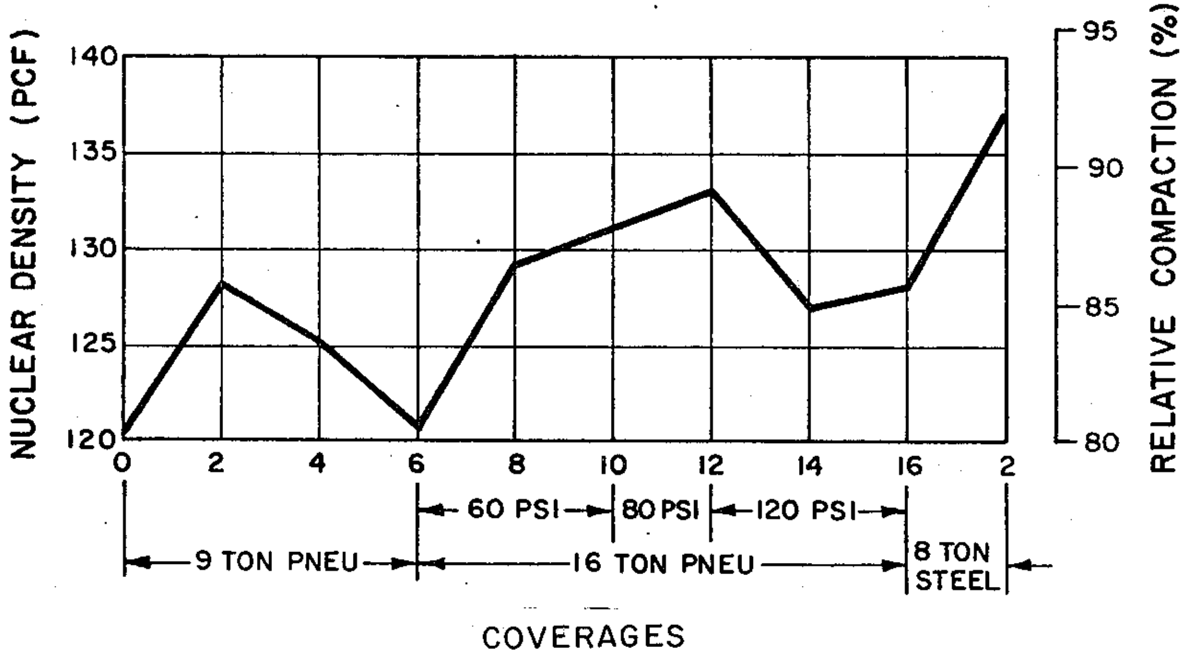
a. Too much time is wasted changing tire pressure;

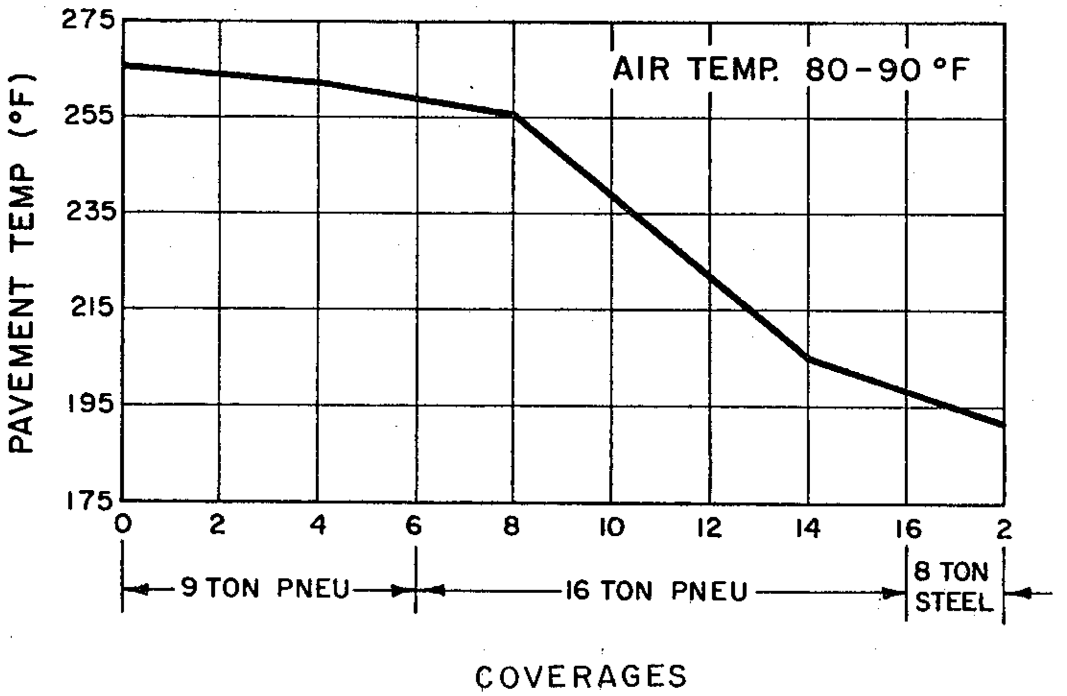
b. At lower tire pressures (30 psi), only the top portion of the pavement is compacted. When the tire pressure is increased to 90, then to 120 psi, the wheels break through the compacted surface and cause decompaction to occur;

c. Heavy pneumatics leave ridges in the asphalt concrete surface.

ASPHALT CONCRETE COMPACTION STUDIES

0.33' BASE COURSE-ONE LIFT





At one test location, two sections were compacted using a 15-ton pneumatic (Michigan). One section was compacted using a tire pressure of 60 psi while the other section was compacted by the same roller with the tire pressure set at 85 psi. The results showed there was no significant difference in density with respect to the change in tire pressure. Based upon this data, tire pressures from 60 to 90 psi are recommended for pneumatic rollers during the intermediate rolling operation. A tire pressure of 90 psi has also been recommended by others for base courses[7].

Another major objection to the use of a pneumatic roller for breakdown rolling is that it cannot come any closer than 10 inches from the edge of the mat without breaking it down; consequently, that portion of the pavement is left uncompacted until the final coverage by a steel roller; by that time, the pavement is generally too cold to adequately compact the edges. The number of coverages needed when using pneumatics for breakdown rolling is also objectionable. Some researchers have indicated that as many as twelve to sixteen coverages were needed for adequate compaction[4].

The results of this study indicate that a 12-ton steel drum tandem or a 3-wheeled steel roller is superior to a heavy pneumatic for breakdown. However, if either of these rollers are used for the breakdown, a pneumatic roller should be used for the intermediate rolling to seal off the surface and make the pavement less permeable to water.

As reported by Mr. R. J. Schmidt[8], et al, high densities and low air voids and permeability provide highly durable pavements. These pavement characteristics can be obtained by using steel breakdown rolling at high pavement temperature followed by intermediate pneumatic rolling and steel finish rolling.

C. Vibratory Compactors

Vibratory compaction for soils has been used since the early 1930's; however, it has only been since the late 1950's that this type of compactor has been tried for compaction of asphalt concrete.

Interim Report No. 3 discusses in detail the results of that phase of this study dealing with vibratory compactors[3]. The data indicated that the following vibratory rollers can be used to meet California's density and other requirements:

a. Essick (VR-54RE)
b. Bomag (BW-200)
c. Vibro-Plus (CC-50-A)
d. Tampo (RS-288-A)
e. Essick (VR-42-RE)

All of the above vibratory compactors can operate at a frequency of 1750 VPM or higher. It was also noted that all of these rollers are self-propelled and utilize all-steel roller drums.

For use on asphalt concrete, the question of whether or not vibratory rolling causes an asphalt flushing problem was also investigated. On one experimental test location, comparison of core sections was made between three vibratory rollers, a pneumatic roller, and the normal static rolling equipment. It was determined that vibratory rollers do cause migration of asphalt coated fines to the surface of the pavement to some extent. However, no problems have occurred that have been attributed to this migration.

The vibratory-compacted sections had lower water permeabilities than did those sections compacted using the normal static and pneumatic procedures. Reducing the water permeability is considered an asset. These subjects have been discussed in more detail in Interim Report No. 3.

There has been some concern that vibratory rollers will leave "waves" in the pavement surface after rolling. From this study, it was found that vibratory rollers operating with a high amplitude (more than 0.050") and low frequencies (less than 1800 VPM) may leave small undulations and give the pavement surface a "wash-board" appearance. However, with some rollers this "wash-board" appearance was reduced by slowing down the speed of the roller to about 1 or 2 miles/hr. and finishing all rolling before the temperature of the pavement dropped below 180°F. These undulations were not noticed when using steel drum vibratory rollers operating above 1800 V.P.M. at an amplitude less than 0.040".

It has been concluded that vibratory and pneumatic breakdown rollers should not be excluded from State projects so long as a final relative compaction of 95 percent is achieved. California Standard Special Provisions now allow the contractor to qualify these rollers. Also, if static breakdown rollers are used, the Standard Special Provisions require a minimum of three coverages during the breakdown phase with a 12-ton steel roller. This is followed by three coverages with a pneumatic and one coverage with a 8-ton static steel finish roller.

Thick-Lift Pavement Density and Smoothness

Several City Engineers in California have developed a preference for thick-lift construction. The most frequently mentioned reasons are:

1. The use of full depth asphalt concrete decreases the total thickness of the structural section required when comparing it with designs including untreated aggregate base. In urban areas, this enables placement of the pavement with a minimum of utility line adjustment.

2. Thick-lift construction is generally faster than normal-lift construction. This reduces traffic congestion and inconvenience. Businesses and homes are restricted from access to the street for a minimum time.

Thus, the fourth objective was to determine if the density and/or riding quality of the highway would be adversely affected by thick-lift construction. Test section densities for lifts ranging from 0.25' to 0.50' have been as high as or higher than the density of the same asphalt concrete mix compacted in normal lifts (no thicker than 0.20'). One reason for this is that the paving machines generally required more time to place a thick-lift, which in turn allows the rolling operators a longer period of time to complete their prescribed rolling pattern. Another reason is that a thick-lift will retain heat for a longer period of time than a thin lift.

However, one major discouraging aspect revealed by this study, which has also been reported by other agencies investigating thick-lift construction, has been smoothness. Even though several different rolling procedures and a variety of compaction equipment were tried, the lowest profile index obtained was approximately 14 inches/per mile. This is twice the amount that is permitted by California specifications for portland cement concrete pavements.

Recently, a profile index survey was made of several thick-lift pavements which had been constructed by other agencies in the past 2 or 3 years. The rolling procedures used for most of these projects consisted of heavy pneumatic (15-25 tons) rollers for compaction for all but the surface course. In all cases, the initial pass was made down the center of the mat prior to rolling towards the edge of pavement. This procedure was recommended by some bituminous engineers who stated that this rolling procedure would improve the rideability of thick-lift pavements. The number of coverages varied with some sections receiving as many as sixteen; however, most of the engineers stated that the pneumatics kept rolling until the mix temperature dropped to about 200°F. The following is a resume of the structural sections and profile indices for the various pavements tested:

Project A.

Street	Limits		Thickness			Avg. Profile Index (in/mi)	
	From	To	1st Base Course	2nd Base Course	Surface	WBTL	EBTL
Steel Lane	Range Ave.	Coffee Ln	5"	5"	1.5"	26	33
W. 3rd St.	RR Track	Hull St.	5"	5"	1.5"	34	26

The first and second asphalt concrete base courses were laid by blade and spreader box. The surface course was placed by a paver, and no leveling devices were used.

The base courses on both of these projects were compacted using a 15-ton pneumatic, varying the tire pressure from 30 to 90 psi, while the surface course was compacted by a 12-ton tandem for the breakdown followed by a pneumatic for intermediate rolling and an 8-ton tandem for the final pass.

Project B.

Street	Limits		Thickness			Avg.Profile Index (in/mi)			
	From	To	1st Base Course	2nd Base Course	Surface	NBL	SBL	WBL	EBL
Wolf Rd.	Britton	Fairoaks	6"	6"	2"	49	47	---	---
10 W.A St.	Mathilda	Sunnyvale	5"	5"	2"	---	---	34	35
Sunnyvale Ave.	Evelyn	Olive	5"	5"	2"	---	36	---	---

The local representative stated that both asphalt concrete base courses were blade laid, while the surface course was laid by a paver. The base courses for the above projects were broken down with an 18-ton pneumatic with tire pressure set at 90 psi, while the surface course was compacted using a 12-ton tandem for the breakdown followed by a pneumatic, and by an 8-ton tandem.

Project C.

Street	Limits		Thickness			Avg.Profile Index (in/mi)	
	From	To	1st Base Course	2nd Base Course	Surface	EB	WB
Campbell Ave.	2nd St.	Harrison	4"	4"	1.5"	38	24
Campbell Ave.	Hwy. 17	Barbanno	4"	4"	1.5"	43	26
Sunnyside Ave	First St.	Winchester	3"	--	2"	34	24
Kennedy Ave.	RXR	Winchester	3"	--	1.5"	30	32

A 15-ton pneumatic was used to compact the base courses, and the 1969 California State Rolling Specification was used for the surface courses.

Project D.

Street	Limits		Thickness			Avg.Profile Index (in/mi)	
	From	To	1st Base Course	2nd Base Course	Surface	EB	WB
W.San Carlos	Race St.	Sunol St.	5.5"	5.5"	2"	37	33

The base courses were blade laid while the surface course was laid by a paver.

Project E.

Street	Limits From	Limits To	Thickness 1st Base Course	Thickness 2nd Base Course	Thickness Surface	Avg. Profile Index (in/mi) NBL	SBL	WBL	EBL
Soto St.	Jackson	Lund	4"	- -	4"	29	28	---	---
Harder Rd.	Soto	Jane	1.5"	- -	1.5"	--	--	19	18

Soto Street and Harder Road were both constructed by the same contractor under the same contract. Soto Street, as shown, is a thick-lift section while Harder Road was constructed using normal lifts. It was reported that the pneumatic (weight unknown) which was to be used for the breakdown became stuck in the thick-lift mat several times. To eliminate this problem, one coverage was made by a 12-ton tandem prior to using the pneumatic.

The rolling procedure used for the surface course on Soto Street and Harder Road was per the 1971 California Standard Specifications.

Project F.

Street	Limits From	Limits To	Thickness 1st Base Course	Thickness 2nd Base Course	Thickness Level	Thickness Surface	Avg. Profile Index (in/mi) EB	WB
Ygnacio Rd.	Bancraft	Wiget	5"	5"	2.5"	2.5"	40	35

Both base courses were blade laid while the 2.5" level and surface courses were placed by a paver. The base courses were compacted by a 16-ton pneumatic using an initial tire pressure of 30 psi which was subsequently increased to 90 psi. The surface course was compacted using California's normal rolling procedure.

The profile indices for the thick-lift sections summarized above for the various projects are generally higher than those measured for thick-lift sections constructed on State jobs. This indicates that whether one begins the breakdown rolling from the center of the pavement and proceeds to the edge or begins at the low edge of the pavement and proceeds to the high edge, the profile indices are extremely high.

It has been found that if these thick-lift base courses are covered with thinner lifts, the profile index will be reduced[1]. For this reason, the California Standard Special Provisions now include limits on thick-lift construction. It has been concluded that until more data is collected, the maximum compacted lift thickness should be no more than 0.4'. The top leveling course should be no more than 0.25' thick and the surface course no more than 0.20' thick after compaction.

REFERENCES

1. Zube, Ernest, "Asphalt Concrete Compaction Studies Using Nuclear Devices", Research Report (633294-1), March 1967.

2. Zube, E., Skog, J., and Cechetini, J., "Compaction of Thick-Lift Asphalt Concrete Pavement", Research Report (633294-2), December 1968.

3. Cechetini, J., "Vibratory Compaction of Asphalt Concrete", Proceedings 49th Annual Meeting of the Association of Asphalt Paving Technologists, Williamsburg, Virginia, February, 1974.

4. Minor, Carl E., "Placing and Compacting Thick-Lifts of Asphalt Concrete", Proceedings 11th Annual Convention, National Asphalt Pavement Association, Las Vegas, Nevada, January 31-February 3, 1966.

5. Rensel, Paul, "Deep Lift Paving", Pacific Builder and Engineer, June 1966.

6. LeClerc, R. V., "Washington's Experience on Thick-Lift Construction of Asphalt Concrete with Pneumatic Breakdown Compaction", Proceedings of the Association of Asphalt Paving Technologists, AAPT Vol. 36, February 1967.

7. Marker, V., "Full Depth Asphalt Concrete Pavement Compaction", The Sixth Annual Nevada Street and Highway Conference, University of Nevada, Reno, Nevada, April 7, 1971.

8. Schmidt, R., Santucci, L., and Garrison, W., "High Temperature Pneumatic Compaction", Highway Research Board Annual Meeting, Washington, D. C., January 1966.

TABLE 1

COMPARATIVE DENSITY STUDY

Contract	Average Density of Cores (P.C.F.)	Average Density by Nuclear Gage* (P.C.F.
A	145	144
B	137	137
C	147	146
D	140	137
E	136	137
F	136	135
G	137	139
H	139	138
I	140	138
J	144	142
K	146	144
L	149	148
Average	141	140

*Backscatter Mode

TABLE 2

COMPACTION STUDY RESULTS

Type Compaction	Field Max. Density (PCF)	Lab. Max. Density (PCF)	Rel. Comp. (%)	Temperature (°F) Start	End	Dist-Co-Rte.
2b*-10**-2f***	137	152	90	200	140	03-Gle-5
2-b-8p-2f	142	156	91.1	255	135	04-CC-4
2b-6p-2f	127	140	91	243	162	05-SB-1
2b-6p-2f	135	151	90	240	165	07-Ora-405
2b-4p-2f	137	151	91	268	238	07-Ora-405
2b-6p-2f	127	145	88	230	105	07-LA-05
2b-6p-2f	133	147	90	300	185	08-Riv-10
2b-6p-2f	133	149	90	200	165	11-Riv-10
2b-6p-2f	133	145	92	231	195	11-Imp-8
2b(8T.Tandem)-6p-2f	137	147	93	275	150	11-SD-8
2b(8T.Tandem)-6p-2f	137	147	93	290	167	11-SD-8
2b-6p-2f	140	147	96	286	227	11-SD-8
2b-6p-2f(8T.Vib.)	138	150	92	250	188	11-Imp-111
2b-2p-1f	139	144	97	280	260	10-Mer-152
2b-8p-1f	131	144	91	275	240	10-Mer-152
2b-12p-1f	137	144	95	265	185	10-Mer-152
4b-10p-2f	139	152	91	190	140	03-Gle-5
4b-10p-2f	133	152	88	230	150	03-Gle-5
4b-6p-2f	139	147	94	275	150	04-Sol-680/21
4b-10p-2f	138	147	93	240	135	04-Sol-680/21
4b-12p-4f	139	147	94	250	175	04-Sol-680/21
4b-4p-2f	129	142	91	230	140	05-SB-1
4b-6p	138	157	88	230	165	05-SBt-156
4b(16T.3L)-8p-2f	148	154	97	280	210	05-Mon-68
4b-6p-2f	138	148	93	225	125	06-Mad-99
4b-2f	132	137	96	235	152	08-SBd-40

* "b" Breakdown coverage by 12 T. Tandem, unless stated otherwise
** "p" Pneumatic, 9 Ton
*** "f" Final coverage by 8 T. Tandem

TABLE 2

COMPACTION STUDY RESULTS

Type Compaction	Field Max. Density (PCF)	Lab. Max. Density (PCF)	Rel. Comp. (%)	Temperature Start	(°F) End	Dist-Co-Rte.
4b-4p-4f	139	154	90	232	150	10-Sac,Ama-16
4b-4p-2f	139	145	95	250	230	11-Imp-8
4b(8T.Tandem)-6f(8T.Vib.)	143	150	96	252	145	11-Imp-8
6b-14p-4f	143	144	99	275	160	04-Sol-680/21
6b-4p-8f	149	156	95	200	140	04-CC-4
6b(8T.Vib.)-6p-2f	144	156	94	255	172	04-CC-4
6b(8T.Vib.)-8p-2f(8T.Vib.)	148	156	95	270	225	04-CC-4
6b-6p-2f	149	157	95	240	136	05-SBt-156
6b-6p-2f	127	140	91	180	142	05-SB-1
6b-2f	132	137	95	268	150	05-SBd-40
6b-6p(16T)-2f	140	150	93	262	235	07-Ora-405
6b-8p-2f	137	147	93	300	120	08-Riv-10
6b-6p-2f	139	147	95	275	200	11-SD-8
6b(8T.Tandem)-6p-4f	141	147	96	270	209	11-SD-8
6b(8T.Vib.)-2p-4f	142	150	95	239	183	11-Imp-111
6b-6p-2f	145	150	97	255	199	11-Imp-111
8p-4b-2f	139	151	92	260	200	03-But-99
8b-8p-2f	145	147	98	260	165	04-Sol-680/21
8b-8p-2f	152	156	97	260	175	04-CC-4
8b-4p-4f	143	154	93	260	145	10-Sac,Ama-16
8b-4p-2f	138	148	93	225	160	11-Riv-10

TABLE 2

COMPACTION STUDY RESULTS

Type Compaction	Field Max. Density (PCF)	Lab. Max. Density (PCF)	Rel. Comp. (%)	Temperature (°F) Start	Temperature (°F) End	Dist-Co-Rte.
8b-6p-2f	138	145	95	230	175	11-Imp-8
8b(8T.Tandem)-12p-4f(12T.Tandem)	142	150	95	263	185	11-Imp-111
8b(8T.Tandem)-12p-4f	140	150	94	239	143	11-Imp-111
8b-12p-4f (12T.Tandem)	139	150	93	256	138	11-Imp-111
8b-(all Vib.)	142	150	95	240	173	11-Imp-111
8b-4p	142	150	95	258	136	11-Imp-111
10b-2p-2f	139	151	93	285	245	07-Ora-405
12b-12p-2f	134	145	92	230	107	07-LA-5
12b-(8T.Vib.)	134	145	92	265	165	07-LA-5
18p-2f	140	151	93	265	190	07-Ora-405

TABLE 3

Project	Thickness of Lift (ft.)	BREAKDOWN PNEUMATIC Number Coverages	%Rel Com.	FINAL STEEL Number Coverages	Rel. Comp.
1	0.33	16	85	2	92
2	0.25	8	87	2	92
3	0.40	6	86	2	93
4	0.25	12	88	NONE	--
5	0.25	14	88	2	93
6	0.33	12	88	1	92

APPENDIX A

ASPHALT CONCRETE.--Asphalt concrete shall be ________ *

and shall conform to the provisions in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

The first, fourth and fifth paragraphs in Section 39-6.01, "General Requirements," of the Standard Specifications are amended to read: 2

All mixtures, except open-graded, shall be spread and compacted at such a temperature that all initial or breakdown compaction shall be performed when the temperature of the mixture is not less than 250° F., except that for layers where the compacted thickness will exceed 0.25-foot, the Engineer may direct that compaction be performed at a lower temperature. Open-graded mixture shall be spread at a temperature of not less than 200° F. and not more than 250° F., unless a higher temperature is directed by the Engineer. 2a

Asphalt concrete and asphalt concrete base shall be spread and compacted in layers. The top layer of asphalt concrete shall not exceed 0.20-foot in compacted thickness. The next lower layer shall not exceed 0.25-foot in compacted thickness, and any lower layers shall not exceed 0.40-foot in compacted thickness. Each layer of asphalt concrete base shall not exceed 0.40-foot in compacted thickness. No layer shall be placed over a layer which exceeds 0.25-foot in compacted thickness until the temperature at mid depth, of the layer which exceeds 0.25-foot in compacted thickness, is not more than 160° F. 2b

Asphalt concrete and asphalt concrete base to be placed on shoulders and other areas off the traveled way having a width of 8 feet or more, shall be spread in the same manner as specified above. When the shoulders and other areas are less than 8 feet in width the material may be deposited and spread in one or more layers by any mechanical means that will produce a uniform smoothness and texture. Unless otherwise shown on the plans, asphalt mixtures shall not be handled, spread, windrowed or stored in such a manner that will stain the finished surface of any pavement or other improvements. 2c

A pass shall be one movement of a roller in either direction. A coverage shall be as many passes as are necessary to cover the entire width being paved. Overlap between passes during any coverage, made to insure compaction without displacement of material in accordance with good rolling practice, shall be considered to be part of the coverage being made and not part of a subsequent coverage. Each coverage shall be completed before subsequent coverages are started. 3

The first, second, third, fourth, fifth and twelfth paragraphs in Section 39-6.03, "Compacting," of the Standard Specifications are amended to read: 4

Initial or breakdown compaction shall consist of 3 coverages of a layer of asphalt mixture and shall be performed with a 2-axle or 3-axle tandem or a 3-wheel roller weighing not less than 12 tons except that other compacting equipment may be used for the initial or breakdown compaction if it has been approved by the Engineer in accordance with Test Method No. Calif. 913 and if it is operated according to the procedures designated in the approval. Such approval will contain the minimum number of coverages required for the specific construction equipment. 4a

Rollers, excepting approved vibratory rollers, shall conform to the provisions in Section 39-5.02, "Rolling Equipment." All rollers shall be equipped with pads and a watering system for the roller wheels which prevent sticking of asphalt mixtures to the pneumatic or steel tired wheels. A parting agent, which will not damage the asphalt mixture, as determined by the Engineer, may be used to aid in preventing sticking of the mixture to the wheels. 4b

Rolling shall commence at the lower edge and shall progress toward the highest portion, except that when compacting layers which exceed 0.25-foot in compacted thickness, and if directed by the Engineer, rolling shall commence at the center and shall progress outwards. 4c

Except when approved vibratory rollers are used for initial compaction, the initial or breakdown compaction shall be followed immediately by additional rolling consisting of 3 coverages with a pneumatic-tired roller. Coverages with a pneumatic-tired roller shall start when the temperature of the mixture is as high as practicable, preferably above 180° F., and shall be completed while the temperature of the mixture is at or above 150° F. Additional compaction with pneumatic-tired rollers will not be required when approved vibratory rollers are used for the initial or breakdown compaction. 4d

Excepting Open Graded asphalt concrete, each layer of asphalt concrete and asphalt concrete base shall be additionally compacted, without delay, by a final rolling consisting of not less than one coverage with a 2-axle tandem roller weighing not less than 8 tons. 4e

During rolling operations, and when ordered by the Engineer, the asphalt concrete shall be cooled by applying water. No layer shall be cooled with water unless ordered or permitted by the Engineer. The water ordered by the Engineer will be paid for as extra work as provided in Section 4-1.03D. 4f

The fifth paragraph in Section 93-1.04, "Measurement," of the Standard Specifications is amended to read: 5

When surfacing material is to be obtained from commercial plants, the products from which will not be devoted to the one project and liquid asphalt is to be paid for as a separate contract item of work, the relative percentages of liquid asphalt and aggregates in the completed mixture, as determined from settings of the batch scales of the mixing plant, will be the basis for computing pay quantities of liquid asphalt. 5a

(Para. 6 is new.)
(To be used when the asphalt concrete grading differs from Standard Specifications.)

(Paragraph 1: Specify type of AC.)
(Paragraph 2: Specify grading.)

(ADVANCE COPY)

39.02
8-27-73

ASPHALT CONCRETE.--Asphalt concrete shall be ______ *

______ and shall conform to the provisions in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

The aggregate shall conform to the ______ 2*

______ grading specified in Section 39-2.02, "Aggregate," of the Standard Specifications.

The first, fourth and fifth paragraphs in Section 39-6.01, "General Requirements," of the Standard Specifications are amended to read: 3

All mixtures, except open-graded, shall be spread and compacted at such a temperature that all initial or break-down compaction shall be performed when the temperature of the mixture is not less than 250° F., except that for layers where the compacted thickness will exceed 0.25-foot, the Engineer may direct that compaction be performed at a lower temperature. Open-graded mixture shall be spread at a temperature of not less than 200° F. and not more than 250° F., unless a higher temperature is directed by the Engineer. 3a

Asphalt concrete and asphalt concrete base shall be spread and compacted in layers. The top layer of asphalt concrete shall not exceed 0.20-foot in compacted thickness. The next lower layer shall not exceed 0.25-foot in compacted thickness, and any lower layers shall not exceed 0.40-foot in compacted thickness. Each layer of asphalt concrete base shall not exceed 0.40-foot in compacted thickness. No layer shall be placed over a layer which exceeds 0.25-foot in compacted thickness until the temperature at mid depth, of the layer which exceeds 0.25-foot in compacted thickness, is not more than 160° F. 3b

Asphalt concrete and asphalt concrete base to be placed on shoulders and other areas off the traveled way having a width of 8 feet or more, shall be spread in the same manner as specified above. When the shoulders and other areas are less than 8 feet in width the material may be 3c deposited and spread in one or more layers by any mechanical means that will produce a uniform smoothness and texture. Unless otherwise shown on the plans, asphalt mixtures shall not be handled, spread, windrowed or stored in such a manner that will stain the finished surface of any pavement or other improvements.

A pass shall be one movement of a roller in either direction. A coverage shall be as many passes as are necessary to cover the entire width being paved. Overlap between passes during any coverage, made to insure compaction without displacement of material in accordance with good rolling practice, shall be considered to be part of the coverage being made and not part of a subsequent coverage. Each coverage shall be completed before subsequent coverages are started. 4

The first, second, third, fourth, fifth and twelfth paragraphs in Section 39-6.03, "Compacting," of the Standard Specifications are amended to read: 5

Initial or breakdown compaction shall consist of 3 coverages of a layer of asphalt mixture and shall be performed with a 2-axle or 3-axle tandem or a 3-wheel roller weighing not less than 12 tons except that other compacting equipment may be used for the initial or breakdown compaction if it has been approved by the Engineer in accordance with Test Method No. Calif. 913 and if it is operated according to the procedures designated in the approval. Such approval will contain the minimum number of coverages required for the specific construction equipment. 5a

Rollers, excepting approved vibratory rollers, shall conform to the provisions in Section 39-5.02, "Rolling Equipment." All rollers shall be equipped with pads and a watering system for the roller wheels which prevent sticking of asphalt mixtures to the pneumatic or steel tired wheels. A parting agent, which will not damage the asphalt mixture, as determined by the Engineer, may be used to aid in preventing sticking of the mixture to the wheels. 5b

Rolling shall commence at the lower edge and shall progress toward the highest portion, except that when compacting layers which exceed 0.25-foot in compacted thickness, and if directed by the Engineer, rolling shall commence at the center and shall progress outwards. 5c

Except when approved vibratory rollers are used for initial compaction, the initial or breakdown compaction shall be followed immediately by additional rolling consisting of 3 coverages with a pneumatic-tired roller. Coverages with a pneumatic-tired roller shall start when the temperature of the mixture is as high as practicable, preferably above 180° F., and shall be completed while the temperature of the mixture is at or above 150° F. Additional compaction with pneumatic-tired rollers will not be required when approved vibratory rollers are used for the initial or breakdown compaction. 5d

Excepting Open Graded asphalt concrete, each layer of asphalt concrete and asphalt concrete base shall be additionally compacted, without delay, by a final rolling consisting of not less than one coverage with a 2-axle tandem roller weighing not less than 8 tons. 5e

During rolling operations, and when ordered by the Engineer, the asphalt concrete shall be cooled by applying water. No layer shall be cooled with water unless ordered or permitted by the Engineer. The water ordered by the Engineer will be paid for as extra work as provided in Section 4-1.03D. 5f

The fifth paragraph in Section 93-1.04, "Measurement," of the Standard Specifications is amended to read: 6

When surfacing material is to be obtained from commercial plants, the products from which will not be devoted to the one project and liquid asphalt is to be paid for as a separate contract item of work, the relative percentages of liquid asphalt and aggregates in the completed mixture, as determined from settings of the batch scales of the mixing plant, will be the basis for computing pay quantities of liquid asphalt. 6a

(To be used when aggregate and binder are paid for as a combined item and quantity is less than 1,000 tons.)

(Para. 1: Specify type of AC.)

39.03
1-2-73

ASPHALT CONCRETE.--Asphalt concrete shall be ________ *

and shall conform to the provisions in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

The amount of asphalt binder to be mixed with the aggregate shall be between 4 percent and 6 percent by weight of the dry aggregate. The exact amount of asphalt binder to be mixed with the aggregate will be determined by the Engineer. 2

The first, fourth and fifth paragraphs in Section 39-6.01, "General Requirements," of the Standard Specifications are amended to read: 3

All mixtures, except open-graded, shall be spread and compacted at such a temperature that all initial or break-down compaction shall be performed when the temperature of the mixture is not less than 250° F., except that for layers where the compacted thickness will exceed 0.25-foot, the Engineer may direct that compaction be performed at a lower temperature. Open-graded mixture shall be spread at a temperature of not less than 200° F. and not more than 250° F., unless a higher temperature is directed by the Engineer. 3a

Asphalt concrete and asphalt concrete base shall be spread and compacted in layers. The top layer of asphalt concrete shall not exceed 0.20-foot in compacted thickness. The next lower layer shall not exceed 0.25-foot in compacted thickness, and any lower layers shall not exceed 0.40-foot in compacted thickness. Each layer of asphalt concrete base shall not exceed 0.40-foot in compacted thickness. No layer shall be placed over a layer which exceeds 0.25-foot in compacted thickness until the temperature at mid depth, of the layer which exceeds 0.25-foot in compacted thickness, is not more than 160° F. 3b

Asphalt concrete and asphalt concrete base to be placed on shoulders and other areas off the traveled way having a width of 8 feet or more, shall be spread in the same manner as specified above. When the shoulders and other areas are less than 8 feet in width the material may be deposited and spread in one or more layers by any mechanical means that will produce a uniform smoothness and texture. Unless otherwise shown on the plans, asphalt mixtures shall not be handled, spread, windrowed or stored in such a manner that will stain the finished surface of any pavement or other improvements. 3c

A pass shall be one movement of a roller in either direction. 4
A coverage shall be as many passes as are necessary to cover the entire width being paved. Overlap between passes during any coverage, made to insure compaction without displacement of material in accordance with good rolling practice, shall be considered to be part of the coverage being made and not part of a subsequent coverage. Each coverage shall be completed before subsequent coverages are started.

The first, second, third, fourth, fifth and twelfth para- 5
graphs in Section 39-6.03, "Compacting," of the Standard Specifications are amended to read:

Initial or breakdown compaction shall consist of 5a
3 coverages of a layer of asphalt mixture and shall be performed with a 2-axle or 3-axle tandem or a 3-wheel roller weighing not less than 12 tons except that other compacting equipment may be used for the initial or breakdown compaction if it has been approved by the Engineer in accordance with Test Method No. Calif. 913 and if it is operated according to the procedures designated in the approval. Such approval will contain the minimum number of coverages required for the specific construction equipment.

Rollers, excepting approved vibratory rollers, shall 5b
conform to the provisions in Section 39-5.02, "Rolling Equipment," of the Standard Specifications. All rollers shall be equipped with pads and a watering system for the roller wheels which prevent sticking of asphalt mixtures to the pneumatic or steel tired wheels. A parting agent, which will not damage the asphalt mixture, as determined by the Engineer, may be used to aid in preventing sticking of the mixture to the wheels.

Rolling shall commence at the lower edge and shall 5c
progress toward the highest portion, except that when compacting layers which exceed 0.25-foot in compacted thickness, and if directed by the Engineer, rolling shall commence at the center and shall progress outwards.

Except when approved vibratory rollers are used for 5d
initial compaction, the initial or breakdown compaction shall be followed immediately by additional rolling consisting of 3 coverages with a pneumatic-tired roller. Coverages with a pneumatic-tired roller shall start when the temperature of the mixture is as high as practicable, preferably above 180° F., and shall be completed while the temperature of the mixture is at or above 150° F. Additional compaction with pneumatic-tired rollers will not be required when approved vibratory rollers are used for the initial or breakdown compaction.

Excepting Open Graded asphalt concrete, each layer of asphalt concrete and asphalt concrete base shall be additionally compacted, without delay, by a final rolling consisting of not less than one coverage with a 2-axle tandem roller weighing not less than 8 tons. 5e

During rolling operations, and when ordered by the Engineer, the asphalt concrete shall be cooled by applying water. No layer shall be cooled with water unless ordered or permitted by the Engineer. The water ordered by the Engineer will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications. 5f

(Para. 6 is new.)
(To be used when the quantity of advance leveling exceeds 500 tons, or is more than 10 percent of total asphalt concrete quantity. An item of asphalt concrete (leveling) should also be included in the Engineer's Estimate.)

(Paras. 1 & 2: Specify type of AC.)

(ADVANCE COPY)

39.04
8-27-73

ASPHALT CONCRETE.--Asphalt concrete shall be ______________________________ *
and shall conform to the provisions in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

Asphalt concrete used for advance leveling as provided in Section 39-6.02, "Spreading," of the Standard Specifications shall be Type _____ and will be paid for at a single contract price per ton for asphalt concrete (leveling). The amount of asphalt binder to be mixed with the aggregate shall be between 4 percent and 6 percent by weight of the dry aggregate. The exact amount of asphalt binder to be mixed with the aggregate will be determined by the Engineer. The contract price paid per ton for asphalt concrete (leveling) shall include full compensation for furnishing all labor, materials (including asphalt binder), tools, equipment, and incidentals, and for doing all the work involved in placing asphalt concrete for advance leveling, complete in place, as shown on the plans, and as specified in this section and in the Standard Specifications, and as directed by the Engineer. 2*

The first, fourth and fifth paragraphs in Section 39-6.01, "General Requirements," of the Standard Specifications are amended to read: 3

> All mixtures, except open-graded, shall be spread and compacted at such a temperature that all initial or break-down compaction shall be performed when the temperature of the mixture is not less than 250° F., except that for layers where the compacted thickness will exceed 0.25-foot, the Engineer may direct that compaction be performed at a lower temperature. Open-graded mixture shall be spread at a temperature of not less than 200° F. and not more than 250° F., unless a higher temperature is directed by the Engineer. 3a

Asphalt concrete and asphalt concrete base shall be spread and compacted in layers. The top layer of asphalt concrete shall not exceed 0.20-foot in compacted thickness. The next lower layer shall not exceed 0.25-foot in compacted thickness, and any lower layers shall not exceed 0.40-foot in compacted thickness. Each layer of asphalt concrete base shall not exceed 0.40-foot in compacted thickness. No layer shall be placed over a layer which exceeds 0.25-foot in compacted thickness until the temperature at mid depth, of the layer which exceeds 0.25-foot in compacted thickness, is not more than 160° F. 3b

Asphalt concrete and asphalt concrete base to be placed on shoulders and other areas off the traveled way having a width of 8 feet or more, shall be spread in the same manner as specified above. When the shoulders and other areas are less than 8 feet in width the material may be deposited and spread in one or more layers by any mechanical means that will produce a uniform smoothness and texture. Unless otherwise shown on the plans, asphalt mixtures shall not be handled, spread, windrowed or stored in such a manner that will stain the finished surface of any pavement or other improvements. 3c

A pass shall be one movement of a roller in either direction. A coverage shall be as many passes as are necessary to cover the entire width being paved. Overlap between passes during any coverage, made to insure compaction without displacement of material in accordance with good rolling practice, shall be considered to be part of the coverage being made and not part of a subsequent coverage. Each coverage shall be completed before subsequent coverages are started. 4

The first, second, third, fourth, fifth and twelfth paragraphs in Section 39-6.03, "Compacting," of the Standard Specifications are amended to read: 5

Initial or breakdown compaction shall consist of 3 coverages of a layer of asphalt mixture and shall be performed with a 2-axle or 3-axle tandem or a 3-wheel roller weighing not less than 12 tons except that other compacting equipment may be used for the initial or breakdown compaction if it has been approved by the Engineer in accordance with Test Method No. Calif. 913 and if it is operated according to the procedures designated in the approval. Such approval will contain the minimum number of coverages required for the specific construction equipment. 5a

Rollers, excepting approved vibratory rollers, shall conform to the provisions in Section 39-5.02, "Rolling Equipment." All rollers shall be equipped with pads and a watering system for the roller wheels which prevent sticking of asphalt mixtures to the pneumatic or steel tired wheels. A parting agent, which will not damage the asphalt mixture, as determined by the Engineer, may be used to aid in preventing sticking of the mixture to the wheels. 5b

Rolling shall commence at the lower edge and shall progress toward the highest portion, except that when compacting layers which exceed 0.25-foot in compacted thickness, and if directed by the Engineer, rolling shall commence at the center and shall progress outwards. 5c

Except when approved vibratory rollers are used for initial compaction, the initial or breakdown compaction shall be followed immediately by additional rolling consisting of 3 coverages with a pneumatic-tired roller. Coverages with a pneumatic-tired roller shall start when the temperature of the mixture is as high as practicable, preferably above 180° F., and shall be completed while the temperature of the mixture is at or above 150° F. Additional compaction with pneumatic-tired rollers will not be required when approved vibratory rollers are used for the initial or breakdown compaction. 5d

Excepting Open Graded asphalt concrete, each layer of asphalt concrete and asphalt concrete base shall be additionally compacted, without delay, by a final rolling consisting of not less than one coverage with a 2-axle tandem roller weighting not less than 8 tons. 5e

During rolling operations, and when ordered by the Engineer, the asphalt concrete shall be cooled by applying water. No layer shall be cooled with water unless ordered or permitted by the Engineer. The water ordered by the Engineer will be paid for as extra work as provided in Section 4-1.03D. 5f

The fifth paragraph in Section 93-1.04, "Measurement," of the Standard Specifications is amended to read: 6

When surfacing material is to be obtained from commercial plants, the products from which will not be devoted to the one project and liquid asphalt is to be paid for as a separate contract item of work, the relative percentages of liquid asphalt and aggregates in the completed mixture, as determined from settings of the batch scales of the mixing plant, will be the basis for computing pay quantities of liquid asphalt. 6a

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

Method No. Calif. 913-B
April 2, 1973
(3 pages)

METHOD FOR EVALUATING THE COMPACTION CAPABILITIES OF ASPHALT CONCRETE COMPACTORS

A. Equipment Qualification

All new compaction equipment, and other compaction equipment as designated, must meet a given relative compaction requirement. Relative compaction is defined as the ratio of the in-place density of the asphalt concrete pavement to the test maximum density (average of 5 specimens) of the same asphalt concrete mix when compacted by the California kneading compactor, Test Method No. Calif. 304.

B. Determining Maximum Density of Test Sections

1. The test section constructed for the purpose of evaluating a given compactor shall be one lane wide, 300 feet in length and marked in 100 foot increments.

2. Prior to testing, the contractor or manufacturer's representative shall specify the operating conditions of the compactor being tested. If a vibratory roller is being tested, these conditions shall include frequency and amplitude. Tire pressure shall be included in the specified operating conditions of a pneumatic roller. Qualification compaction tests can be made on any Type A or Type B asphalt concrete mix. However, if the roller has previously been qualified on a Type B mix with a ¾" maximum aggregate, either coarse or medium grading, additional qualification can be waived at the discretion of the engineer.

3. The temperature of the asphalt concrete mix at mid-depth shall be between 270–280°F at the beginning of the breakdown rolling. The compacted thickness limits shall be between 0.20 to 0.30 of a foot. Rolling of the test section shall continue until:

a. 95 percent relative compaction is obtained, or

b. No appreciable increase in density is obtained by additional rolling.

4. When the compactor being tested has met the above requirements, a final coverage shall be made by an 8-ton tandem (steel) roller, or by a compactor that exerts pressure equivalent to the pressure (lbs. per lin. inch) exerted by an 8-ton tandem (steel) roller.

5. Within each 100 foot increment of the 300 foot test section, take ten (10) one minute readings with a nuclear density gage. Select the location of each test by a statistical method such as the nonbiased sample cards, or random numbers.

6. For the acceptance of a specific compactor, the mean density for the ten locations of each 100 foot test section shall be a minimum of 95% relative compaction, and none of the individual tests shall be below 92% relative compaction. Other reasons for nonacceptance will include ridges, indentations or other objectionable marks in the asphalt concrete after final rolling has been completed.

7. Record acceptable operating conditions for approved equipment on Form HMR T-3133 as shown in Fig. I.

REFERENCE

Test Method No. Calif. 304

End of Text on Calif. 913-B

CALCULATION EXAMPLE

	Passed Test Section Table 1			Failed Test Section Table 2		
Sta Density	368+50 to 369+50 (lbs/ft³)	369+50 to 370+50 (lbs/ft³)	370+50 to 371+50 (lbs/ft³)	117+25 to 118+25 (lbs/ft³)	118+25 to 119+25 (lbs/ft³)	119+25 to 120+25 (lbs/ft³)
1	138	138	140	137	138	136
2	139	139	138	138	137	138
3	138	138	137	136	136	137
4	137	136	140	137	139	140
5	138	138	138	136	137	138
6	140	139	139	138	136	*133
7	138	137	141	139	138	136
8	138	140	138	137	135	*133
9	139	136	139	135	136	139
10	137	138	138	136	134	138
Average	138.2	137.8	138.8	136.9	136.6	136.8
Relative Compaction	95.3%	95.1%	95.7%	95.1%	*94.9%	95.0%

Table 1: Based on Density of Compacted Specimens of 145 lbs/ft³

Table 2: Based on Density of Compacted Specimens of 144 lbs/ft³

*Any one of these values would have failed the roller for State work.

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT

REPORT OF TESTS ON

District	County	Route	P.M.	Date Tested
Contractor			Manufacturer	
Model #	Weight	Freq. Range	Ampl.	
ACCEPTED OPERATING CONDITIONS	Freq.	Amp.	Max. Speed	No. of Coverages
SPECIFICATIONS				
REMARKS				

DATE TESTED:	
TESTED BY:	
APPROVED BY:	

HMR T- (11-71)

FIGURE I

CT Lab Sacto 5-74 200

D-5-26
2-74