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Experimental Use of Rubber-Tire Rollers as a Means of Improving Density in Asphalt Overlays

Author(s)

C. S. Hughes

Performing Organization Name and Address

Virginia Transportation Research Council
Box 3817, University Station
Charlottesville, Virginia 22903-0817

Sponsoring Agencies' Names and Addresses

Va. Dept. of Transportation
1221 E. Broad Street
Richmond, Virginia 23219

University of Virginia
Charlottesville
Virginia 22903

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FINAL REPORT

EXPERIMENTAL USE OF RUBBER-TIRE ROLLERS AS A MEANS OF IMPROVING DENSITY IN ASPHALT OVERLAYS

C. S. Hughes
Senior Research Scientist

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
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ABSTRACT

This study reports the results of comparative tests on sections of asphalt pavement rolled with conventional steel-wheel rollers and those rolled with a rubber-tire roller added between the steel-wheel breakdown and steel wheel finish rollers. Nuclear density and air voids were used as measures of potential differences between sections. Of the 15 projects tested, which included 90 comparisons of averages and standard deviation, the sections rolled with the rubber-tire roller added were statistically significantly ($\alpha = .05$) "better" in only 11 percent. Sections rolled with the conventional steel-wheel rollers were statistically significantly ($\alpha = .05$) "better" in 13 percent. In the author's opinion, this does not indicate that the addition of the rubber-tire roller was actually detrimental. There were most likely other variables in the pavement, rolling, and/or testing that created the differences. However, it is obvious that this testing showed no consistent measurable benefit as a result of the addition of a rubber-tire roller.

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INTRODUCTION

There has been much discussion during the last few years in Virginia (and nationwide) concerning the benefits of using rubber-tire rollers to compact asphalt concrete. The primary reason for the renewed interest in using rubber-tire rollers in the intermediate roller position (i.e., following the steel-wheel breakdown and preceding the steel-wheel finish rollers) is that they are purported to reduce rutting problems.

Virginia conducted two studies (one in 1987[1] and one in 1988[2]) in which asphalt concrete properties of sections rolled with the addition of the rubber-tire rollers were compared to the properties of sections rolled with conventional rollers. The results were mixed. On several of the roads, the properties of the mixes from sections rolled using a rubber-tire roller were better than from sections rolled with conventional rollers.

Following the 1988 study, a recommendation was made that all modified mixes (those designed with a 75-blow compactive effort) used in the state should require four passes with a rubber-tire roller that had a minimum of 80 psi ground contact pressure (GCP). Modified mixes were chosen because they have a lower asphalt content, and it is generally more difficult to increase their density than to increase the density of unmodified mixes. The implementation of this recommendation has been postponed primarily because the results of the field studies were mixed but also because a survey of other states' practices indicated a lack of agreement as to the benefits of using rubber-tire rollers.

Two of the reasons that consistent results have not been obtained are the relatively small number of experimental sites in each study and the relatively large variabilities found.

In an effort to determine whether the use of rubber-tire rollers does provide a consistent improvement in pavement properties, this study included a larger number of test sections than the previous studies in an attempt to reduce the influence of testing and sampling variabilities.

PURPOSE AND SCOPE

The purpose of this study was to determine the effectiveness of using a rubber-tire roller in the intermediate roller position to compact asphalt pavements. The field compaction sections were coordinated, tested, and inspected by district and residency personnel. It was the responsibility of the Research Council to analyze the data and prepare a report.

Seventeen pavements from the maintenance schedules were selected on which it was required that a rubber-tire roller be used on one-half the length of each. All of the pavements required mixes with the design asphalt content determined by a 75-blow compactive effort. The contractor's conventional rollers (steel wheel) were used on the other half of the length of the pavements in each schedule. A list of the schedules is in Appendix A. Appendix B contains guidelines followed in gathering data for use in analyzing the results.

The special provision that was attached to each maintenance schedule required that the rubber-tire roller have a minimum GCP of 80 psi and that four passes be made with it through the test section. Because GCP is influenced by roller weight, tire pressure, and ply of tire, it was the contractor's responsibility to determine that the minimum GCP was obtained.

TESTING

Each project was set up so that the first half of the length was rolled with the contractor's conventional rollers using the roller pattern established for that project. This section was called the control section. The second half of the project used the same equipment and roller pattern as used on the control section with the exception that four passes were added with the rubber-tire roller used in the intermediate position. There was some concern in the field that adding the rubber-tire roller to the rolling pattern that was established to provide maximum density without the rubber-tire roller would cause overcompaction and an increase in air voids rather than a decrease as desired. This concern proved ill-founded as will be discussed later.

The traffic lane was paved after the passing lane so that the confined joint at the centerline could be rolled with both compaction trains. This procedure allowed a comparison of the densities at the joints, reduced the amount of testing that was required, and restricted the testing to the traffic lane. Nuclear tests were made transversely across the pavement at 0.1-mile intervals (on projects 4 miles in length or more, this interval was increased to 0.2 miles to reduce testing). At each transverse location, 10 nuclear readings were taken at 1-foot intervals beginning immediately adjacent to the longitudinal joint; thus, the tenth reading was in close proximity to the shoulder edge.

A minimum of 8 cores were taken from the control and 8 from the test section for the measurement of air voids. At least 3 were taken within 1 foot of the longitudinal joint.

The purpose of these tests was to determine

- whether the longitudinal joint was more densely compacted by using a rubber-tire roller
- whether the density was more uniform across the pavement with the addition of the rubber-tire roller
- whether the use of the rubber-tire roller reduced the average air voids in the pavement.

RESULTS

Although initially 17 pavements were selected for testing, only results from 15 were available for analysis. The project on I-81 in Washington County was completed without the addition of the rubber-tire roller because of an oversight. The project on I-95 in Prince William County was constructed as required and tested, but a breakdown of the nuclear gauge used on that project during testing necessitated a change in gauges. But the data were sufficiently inconsistent as to raise questions concerning the accuracy of the results. To remove this doubt, the data were not included in the analysis.

The results are shown in Table 1. The averages and standard deviations for all measurements are shown. The control and test sections for each project are compared for nuclear density, both full width and on the joint, and for air voids. The asterisks will be discussed subsequently. The number of tests, n, for each measurement is shown because of its influence on the analysis.

ANALYSIS

Statistical analyses were conducted on the data to compare the averages and standard deviation between test and control sections for both nuclear densities and air voids. For the comparison, the *t* test and the *F* test were used for the averages and standard deviations (or variances), respectively, both at a significance level of 0.05. The number of samples is important because the critical *t* and *F* values are related to n.

Asterisks are used to designate not only that a statistically significant difference is indicated but also whether the control sections are better than the test section or vice versa.

Table 1

Rubber-Tire Roller Study Results

Rte		Nuclear Density, pcf								Air Voids			
		Full Width				Joint				%			
		n	Control	n	Test	n	Control	n	Test	n	Control	n	Test
29N#	$\bar{X}$	140	138.4	140	139.1	14	136.0	14	134.6	8	11.0	8	11.6
	Std		3.09		3.99		3.30		4.40		1.82		1.47
220	$\bar{X}$	110	144.4	120	143.7	11	143.2	12	144.5	4	10.6	4	9.6
	Std		3.34		3.08		4.96		4.59		2.16		1.38
29C	$\bar{X}$	100	140.6	100	140.3	10	141.4	10	140.0	8	10.6	8	9.8
	Std		3.96		3.20*		3.13		2.43		1.65		1.81
72	$\bar{X}$	240	131.6	240	132.5*	24	132.9	24	133.7	8	10.6*	8	12.2
	Std		3.42*		3.98		3.53		4.15		1.22		1.62
64A	$\bar{X}$	200	146.0*	220	144.9	20	144.5*	22	142.0	10	9.8	10	10.2
	Std		3.71		3.77		4.04		2.74*		1.55		1.49
64G	$\bar{X}$	150	137.5*	150	134.5	15	135.5*	15	132.8	8	9.1	8	11.1
	Std		2.97*		4.17		3.61		3.58		3.69		2.91
360	$\bar{X}$	160	138.6	170	139.3	16	137.3	17	137.5	8	11.6	8	10.1
	Std		3.72		3.06*		4.05		2.49*		4.53		1.64*
301S	$\bar{X}$	160	137.4	180	137.7	16	137.9	18	136.8	8	10.2	9	9.9
	Std		3.32		3.48		1.86*		3.12		3.88		3.48
216	$\bar{X}$	110	133.4	110	135.0	11	133.9	11	138.1*	9	11.0	9	9.2
	Std		5.16		4.04*		2.25		4.27		0.75*		3.46
85	$\bar{X}$	190	138.2	200	137.7	19	137.3*	20	135.1	8	8.6	8	7.6
	Std		3.29		3.72		3.76		2.60		3.18		3.84
15-2C	$\bar{X}$	100	142.5	110	144.2*	10	145.1	11	145.9	8	8.7	8	8.4
	Std		3.51		3.53		2.54		3.64		3.33		4.43
15-3C	$\bar{X}$	90	143.4	110	147.0*	9	144.3	11	145.8	8	10.0	8	7.9
	Std		3.96		3.47		2.09		2.61		3.93		4.45
301N	$\bar{X}$	140	143.5	150	143.7	14	140.3	15	139.5	9	12.8	9	12.4
	Std		3.58*		4.62		1.89*		3.27		1.95		1.56

continues

Table 1 (cont.)

Rte		Nuclear Density, pcf								Air Voids			
		Full Width				Joint				%			
		n	Control	n	Test	n	Control	n	Test	n	Control	n	Test
134	$\bar{X}$	140	129.4	150	130.4	14	128.8	15	130.0	8	12.9	8	13.5
	Std		4.66		5.25		4.10		3.32		1.07		2.06
77	$\bar{X}$	180	136.3	170	135.9	18	133.7	17	131.6	7	9.8	7	9.2
	Std		4.98		4.90		6.01		5.15		2.01		2.74
Grand Average			138.7		139.1		138.1		137.9		10.5		10.2
Standard Deviation of Averages			4.80		4.91		4.88		5.07		1.29		1.70

#Letters are county initials to differentiate between projects on the same route.

Nuclear Density

Of the 15 projects, the averages for the full-width measurements were only significantly different on 5. Of these, the test section averages were higher on 3 and the control section averages were higher on 2. For joint density, 4 projects had significant differences indicated between averages; 3 were better on control sections and 1 was better on the test section. For the comparison of standard deviations, the full-width measurement results on 6 projects indicated a significant difference; 3 control sections were more uniform than the comparable test section, and 3 test sections were more uniform than the control section. The results of standard deviation comparisons on joint density had 4 cases of a significant difference; the control and test sections were each more uniform on 2 projects.

Air Voids

Comparing the averages of air voids obtained from cores indicated only 1 case where a statistically significant difference was found. On this project, the average air voids in the control section was significantly better than in the comparable test section. As for comparing variabilities, two occurrences of significant *F* values indicated that the test section was more uniform than the control section on one project, and the control was more uniform than the test section on the other. In the latter case, the significant difference was the result of the unusually low (uniform) standard deviation of the control section.

DISCUSSION

Of 90 comparisons of averages and standard deviations, a statistically significant difference was found on only 22 (24 percent). Of the 22, the test section was significantly "better" in 10 cases.

Also, of the 22 cases of a significant difference, 19 were found through nuclear testing. Part of the reason for more occurrences of a significant difference is likely the result of the larger number of tests, which influences the statistical analysis.

This testing showed no consistent measurable benefit by the addition of the rubber-tire roller. It is possible that overrolling with the rubber-tire roller reduced the density and thus made the control sections appear to have higher densities. This is highly unlikely because of the relatively high air voids measured on most of the projects. Overrolling is normally only encountered when air voids are 5 percent or less.

There was an extensive amount of testing performed in this study that allows an analysis of the results beyond the effect of the rubber-tire roller. The summary statistics at the bottom of Table 1 show some surprising trends. It has been assumed that the density at the joint is almost always appreciably less than that of the rest of the roadway. But the average density of the full-width control sections was only 0.6 pcf higher than the average of the control section joint densities; the average density of the full-width test sections was 1.2 pcf higher than the average of the test section joint densities. Also, the standard deviation of the averages ($\sigma_{\bar{x}}$) measured on the full-width sections was not appreciably lower than that measured on the joint.

In calculating the variability, on several occasions, very large differences occurred within the 10 measurements at a transverse location. An example is shown in Table 2. The low reading at location 10 (shoulder) is not as worrisome as the very high reading at location 3. Was this an accurate reading? Did the gauge malfunction? Did the operator misread the density? This data point should have been questioned by the person doing the testing. The standard deviation of 6.7 pcf is considerably higher than an acceptable value of about 4 pcf. Another example of questionable variability are two sets of adjacent transverse readings on either side of a bridge shown in Table 3. These averages are statistically significantly different at an $\alpha = .05$. The results are from the same project; the locations were rolled with the same roller and supposedly with the same roller pattern; yet, there is a 95 percent chance the results are not from the same population. What changed from one side of the bridge to the other?

Another concern is the relatively high air voids both in averages and standard deviations. Only 2 of the 15 projects had air voids below 9 percent. Most asphalt technologists indicate that the durability of pavements with air voids exceeding 9 percent will be considerably less than pavements with air voids in the 5 to 8

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Table 2

Nuclear Density Measurements at a Transverse Location

Transverse Measurement No.	Nuclear Density, pcf
1 (Joint)	140.9
2	137.7
3	152.4
4	135.2
5	138.2
6	131.0
7	130.8
8	138.0
9	137.9
10 (Shoulder)	128.6
$\bar{X}$	137.1
Standard Deviation	6.70

Table 3

Nuclear Density Measurements at Two Transverse Locations

Transverse Measurement No.	Nuclear Density, pcf	
	Location 1	Location 2
1	143.9	123.1
2	140.6	128.3
3	139.1	135.8
4	139.7	138.1
5	142.1	137.4
6	142.8	133.7
7	133.7	131.9
8	138.5	137.8
9	135.8	127.6
10	133.1	130.2
$\bar{X}$	138.9	132.4
Std. Dev.	3.72	5.07

percent range. This is particularly true for pavements with thin asphalt films, which is the case with asphalt content determined with a 75-blow compactive effort. Thus, the durability of these pavements should be questioned. A previous density specification used in Virginia used a standard deviation for air voids of 1.3 percent to indicate an acceptable variability. Only 3 of the 30 sections in this study had a variability that would meet that criterion, and there were 3 sections with standard deviations of the air voids over 4.0 percent.

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CONCLUSIONS

1. Neither nuclear densities nor air voids were consistently better using a rubber-tire roller in the compaction train.

2. No overrolling occurred when the rubber-tire roller was added to the conventional compaction train used to establish the roller pattern.

3. The average nuclear density measured at the joint was only 0.9 pcf lower than that measured on the full-width of pavement.

4. The relatively high air voids found on most projects is an indication that the durability of these projects will be less than desirable.

RECOMMENDATION

Although a consistent improvement over conventional rollers was not measured when a rubber-tire roller was added, when the required density is not met consistently using conventional rollers, construction personnel should consider among other alternatives adding a rubber-tire roller.

REFERENCES

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2. Hughes, C. S. 1989. "Final Report: Evaluation of the Use of Rubber-Tire Rollers on Asphalt Concrete." Virginia Transportation Research Council. VTRC 89-R26. Charlottesville, Va.

APPENDIX A

Maintenance Schedules

Item	Dist	County	Rte	Lane	Length	Mix
1-M-90	1	Washington	I-81	SBL	4.04	SM-2C
1-B-90	1	Dickenson	72	Both	5.00	SM-3C
2-A-90	2	Carroll	I-77	SBL	3.58	SM-3C
2-F-90	2	Franklin	220	NBL	4.77	SM-2C
3-B-90	3	Nelson	29	NBL	3.36	SM-2C
3-C-90	3	Campbell	29	NBL	4.93	SM-2C
4-E-90	4	Nottoway	360	EBL	3.59	SM-2C
4-P-90	4	Goochland	I-64	WBL	3.07	SM-2C
4-Q-90	4	Mecklenburg	I-85	SBL	4.00	SM-2C
5-8-90	5	Sussex	301	SBL	3.69	SM-2B
5-D-90	5	York	134	EBL	3.77	SM-2B
6-C-90	6	King George	301	NBL	5.60	SM-2C
6-A-90	6	Gloucester	216	Both	3.61	SM-3C
7-G-90	7	Fauquier	15	NBL	2.33	SM-3C
7-G-90	7	Fauquier	15	NBL	4.91	SM-2C
8-F-90	8	Alleghany	I-64	EBL	4.64	SM-2B
A-E-90	A	Pr. William	I-95	SBL	3.55	SM-2C

APPENDIX B

Guidelines Used in Gathering Data

GUIDELINES FOR EVALUATING A RUBBER-TIRE ROLLER

Tests are to be made on both the control section (the section on which conventional rollers are used) and on the test section (the one with the rubber-tire roller in the intermediate roller position). This testing is in addition to whatever testing is needed for project acceptance and only applies to the surface course.

The purpose of these tests is to determine:

1. whether the longitudinal joint is more densely compacted by using a rubber-tire roller
2. whether the density is more uniform across the pavement with the use of the rubber-tire roller
3. whether the use of the rubber-tire roller reduces the average air voids in the pavement.

In order to make these determinations, the following paving and testing sequences are necessary.

1. The roller pattern should be determined on the control section as is normally done. The first half of the length shall be rolled using this roller pattern. The second half of the length shall be rolled similarly to the first half except the rubber-tire roller with a minimum of 80 psi GCP shall make four passes throughout this section. The passing lane is to be paved first and the traffic lane paved second. This will allow the necessary testing to be restricted to only the traffic lane. This testing will take place after the completion of the rolling of each section but before the lane is opened to traffic.
2. At 0.1-mile intervals, nuclear testing across the pavement is to be conducted.
    a. The first nuclear reading is to be taken with the nuclear gauge entirely in the traffic lane and the edge of the gauge directly adjacent to the longitudinal joint.
    b. The gauge is to be moved transversely approximately one foot and another reading taken.
    c. This procedure is to be repeated until 10 readings have been taken in the transverse direction.
    d. The 10th and last reading should be near (within one foot) of the unsupported edge on the shoulder side of the road.
3. A minimum of eight cores from the control section and eight cores from the test section will be taken. *At least* three of the eight cores shall be taken as close to the longitudinal joint as practical (within one foot), but

they should not straddle the joint. The other cores shall be taken randomly (longitudinally and transversely) to adequately cover each section. The cores will be taken to the District Materials Laboratory for the determination of air voids.

4. Report the air void data of each individual core with the cores from areas near the joint designed.