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VIBRATORY ROLLER STUDY

by

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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FOREWORD

Recently, much criticism has been directed toward the use of vibratory rollers to compact bituminous concrete. The results of the study reported here indicate that when these rollers are operated properly they can produce dense, strong, smooth riding pavements. It is important that, as with any equipment, the rollers be used properly. Therefore, suggested precautions and practices are listed below.

1. The roller operator should be thoroughly familiar with the roller.

2. The roller should be well-maintained. This is particularly true of the frequency and amplitude mechanisms.

3. When rolling, the following vibratory settings should be used:

    a. Frequency — minimum 1,800 vpm

    b. Amplitude — low on surface courses (for smoothness), high on bituminous base courses

    c. Speed — maximum 3 mph

4. The roller should not be allowed to vibrate when standing or reversing direction.

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INTRODUCTION

At the spring 1982 meeting of the Bituminous Research Advisory Committee, it was requested that the Council undertake a study to determine if compaction by vibratory rollers was detrimental to bituminous pavements. This request was made after some committee members recounted instances in which heavy vibratory rollers were operated improperly and apparently damaged the pavement structure.

The Council agreed to undertake such a study as a cooperative effort of the coauthors of this report.

STUDY APPROACH

It was decided that the properties likely to be detrimentally affected by vibratory rolling were road roughness, deflections, and density. To obtain a measure of the improvement or detriment resulting from the use of vibratory rollers control sections on which compaction was achieved with a typical rolling pattern were necessary and road roughness and deflection tests had to be made before and after paving.

Furthermore, it was decided that the rollers, both vibratory and static, should be used in an acceptable manner as opposed to trying to create a failure. (This was predicated on the fact that many pieces of construction equipment can cause failures if used improperly.) In an attempt to normalize the test sections, the control density was that resulting from the typical rolling pattern used and that became the target density in the companion "experimental" section. This was done so that the type of compaction equipment rather than maximum density would be the independent variable.

TEST SECTIONS

Six surface overlay projects were tested with each section being at least 0.5 mile long. The general locations and roller information are shown in Table 1. Two vibratory sections were tested on Route 33E because the contractor was using a high amplitude setting on the roller to compact the overlay before the study began. This is contrary to recommended practice because it usually induces a rough riding surface. The contractor was doing this because in the low amplitude mode only one drum was vibrating. Since the test data eventually indicated a difference between the sections rolled with high and low amplitude settings, the two settings were tried again on Route 33W when the roller operated properly in both vibratory modes.

DATA COLLECTION

As previously mentioned, road roughness and deflection tests were performed before and after paving, the only exception being on Route 60, where the paving began before deflection tests could be obtained. Density was monitored during construction with a nuclear density gauge, and then 4" x 4" density plugs taken for acceptance tests were used as the basis for density analyses.

RESULTS

Density

The nuclear and conventional density results are shown in Table 2. Generally, so few conventional density tests were run on each section as to make the calculation of a standard deviation questionable.

Table 1

Vibratory Roller Sections

		Vibratory Section				Static	
Rte.	County	Roller Type	Amplitude	Frequency, VPM	Speed, MPH	Roller Type	Speed, MPH
60	Appomattox	Dynapac CC-42A	low	2300	2.5	Static*	2.7
220	Henry	Dynapac CC-50	low	1800	3.4	Static*	3.4
250	Henrico	Tampo 166A	low	2200	3.6	Gallion 8-12 ton	4.2
29	Nelson	Dynapac CC-42A	low	2300	2.8	Static*	3.0
33E	Rockingham	Dynapac CC-42A	high	2300	5.6	Static*	7.8
33E	Rockingham	Dynapac CC-42A	low	2600**	5.6	-	-
33W	Rockingham	Dynapac CC-42A	high	2300	3.6	Static*	6.2
33W	Rockingham	Dynapac CC-42A	low	2500	4.0	-	-

* Roller same as in vibratory section, but operating in static mode.
**Only one drum vibrating

Table 2

Density Results

Rte.	Vibratory				Static			
	No. Passes	Nuclear, lb./ft.^{3} $\bar{X}$	σ	Conv. %* $\bar{X}$	No. Passes	Nuclear, lb./ft.^{3} $\bar{X}$	σ	Conv. %* $\bar{X}$
60	5V-2S	133.5	3.4	93.0	9	131.5	3.3	93.8
220	2V-3S	142.8	4.7	91.8	6	143.6	2.6	91.6
250	2V-2S	131.1	2.5	92.1	6	130.3	2.6	90.6
29	2V-2S	136.4	3.7	92.0	6	139.9	2.8	91.3
33E (Hi)	2V-2S	138.3	3.6	93.7	-	-	-	-
(Lo)	3V-2S	135.0	3.6	91.3	7	133.2	3.4	90.4
33W (Hi)	3V-2S	136.6	4.1	91.0	-	-	-	-
(Lo)	3V-2S	132.9	3.4	89.0	7	132.3	2.4	89.1
	$\bar{X}$	135.8	3.6	91.7	$\bar{X}$	135.1	2.8	91.1

*% Maximum Theoretical Density

As the density results show, even though an attempt was made to obtain the same average density on the sections compacted by rollers in the static mode as that obtained on the section using the vibratory mode, this was not always accomplished. As shown in Table 2, this was so even though in most cases 2 more passes were used on the static sections. The average density for the vibratory sections was slightly higher than that for the static sections. Although the improper use of the high amplitude setting led to some of the difference in the average densities of the two sections, there is still a slightly higher average for the vibratory than for the rollers used in the static mode when the section using the high amplitude settings are eliminated. It will also be noted that the average densities were higher on the Route 33E section than on the later-built Route 33W section. This was apparently caused by a change in mix gradation.

The standard deviations of the nuclear tests indicate a slightly higher variability in the results for the vibratory sections than in those for the static sections.

Roughness

The roughness results are shown in Table 3, where the most important thing to note is the amount of roughness removed by the overlay.

The average results shown in Table 3 under "difference" indicate that the rollers operating in the static mode removed a greater amount of roughness than did those operating in the vibratory mode. However, if the sections compacted with the vibratory rollers operating with the high amplitude setting are eliminated, the average differences increase from 14.7 in./mi. and 15.6% to 17.2 in./mi. and 17.9%, respectively, more closely approaching the difference values for the static section. This result affirms what has been known and taught for several years; i.e., although the use of a high amplitude setting may increase the density on surface courses, it almost certainly will adversely affect road roughness.

In comparing the after results in the static sections with those of the vibratory sections, it does not appear that the latter are by any means unacceptable.

Table 3

Roughness Results

Route	Vibratory				Static			
	Before in./mi.	After in./mi.	Difference in./mi.	Difference %	Before in./mi.	After in./mi.	Difference in./mi.	Difference %
60	89.9	77.9	12.0	13.4	106.3	83.7	22.6	21.3
220	121.0	87.4	33.6	27.8	98.0	83.0	15.0	15.3
250	83.0	75.9	7.1	9.6	77.2	69.9	7.3	9.5
29	92.0	83.2	8.8	9.6	97.2	85.3	11.9	12.2
33E (Hi)	79.7	75.0	4.7	5.9	-	-	-	-
33E (Lo)	80.9	63.8	17.1	21.1	113.6	79.7	33.9	29.8
33W (Hi)	77.4	68.7	8.7	11.2	-	-	-	-
33W (Lo)	96.5	71.6	24.9	25.8	90.8	61.7	29.1	32.0
$\bar{X}$	90.1	75.4	14.7	15.6	97.2	77.2	20.0	20.0

Deflection Tests

The results of deflection tests are summarized in Table 4. As noted earlier, the Route 60 section was paved before deflection data could be collected. In addition, the Routes 250 and 33W (low amplitude) vibratory sections were placed on sites where no deflections were run prior to the overlay. In the table, the effect of the overlay and roller types on pavement structure is given in two ways: (1) as a reduction in deflection (as a percent of the original deflection), and (2) as an increase in the thickness index (as a percent of the original thickness index).

Table 4

Deflection Results

	% Reduction in Deflection		% Increase in Thickness Index	
Route	Static	Vibratory	Static	Vibratory
220	44.0	40.0	34.9	80.0
250	13.6	-	11.3	-
29	11.1	51.6	14.6	51.5
33E (Hi)	42.8	38.5	27.0	66.7
33E (Lo)	42.8	40.0	27.0	45.9
33W (Hi)	21.1	25.0	18.8	24.1
33W (Lo)	21.1	-	18.8	-
Avg.	26.5	39.0	21.3	53.6

As shown by the average values in Table 4, the vibratory compaction was slightly more effective in reducing pavement deflections. Overlays so compacted are much more effective in increasing the pavement thickness index than are those compacted with static rolling. It is speculated that this unexpected result may be related to a reorientation of the materials in the underlying pavement layers such as crushed aggregate bases. The small differences in density between the static and vibratory sections seem to preclude any major structural alteration in the surface courses due to vibratory rolling.

There is nothing in the deflection test results and analyses to indicate that vibratory rolling is detrimental to the pavement structure. In fact, one could argue that, from a structural standpoint, vibratory rolling appears to be beneficial.

CONCLUSIONS

This study has indicated that vibratory rollers, when operated properly, do not detrimentally affect a bituminous overlay, and, because vibratory rolling gives improved deflections, it may be more beneficial than static rolling. The important fact that must be kept in mind is that the vibratory rollers must be well-maintained and operated properly.

SUMMARY

This study has affirmed that benefits can be achieved from compaction with vibratory rollers when care is taken to follow the practices given below.

1. The roller operator should be made thoroughly familiar with the roller.

2. The roller should be well-maintained. This is particularly true of the frequency and amplitude mechanisms.

3. When rolling, the following vibratory settings should be used:

   a. Frequency — minimum 1,800 vpm

   b. Amplitude — low on surface courses (for smoothness), high on bituminous base courses

   c. Speed — maximum 3 mph

4. The roller should not be allowed to vibrate when standing or reversing direction.

When these practices are followed smooth, dense pavements can be constructed.