VIBRATORY COMPACTION OF BITUMINOUS CONCRETE — WHERE DOES IT STAND?

by

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(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

Charlottesville, Virginia

September 1974
VHTRC 75-R7

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INTRODUCTION

Under the normal conception the compaction of bituminous concrete is accomplished by breakdown, intermediate and finish rolling. Because the demarkation between each of these stages is vague, often only two types of rollers are used. Traditionally, the static three-wheel breakdown and tandem finish rollers have been used for this purpose. However, rubber tired rollers have also found a place in many compaction trains for breakdown or intermediate rolling. Recently, vibratory rollers have become more commonplace, being used for either breakdown, finish, or both.

The use of vibratory compaction began on cohesionless soils and aggregates in the 1950's. Eventually, the rollers used on these materials were tried on bituminous concrete with generally poor results. The aggregate rollers had a relatively low frequency and a high amplitude, which were ideal for cohesionless materials but unsuitable for viscoelastic bituminous concrete. This conclusion has been documented by the California Division of Highways,(1) among other states. This poor early performance is probably one reason that acceptance of vibratory rollers for compacting bituminous concrete has been somewhat slow.

The vibratory compaction of bituminous concrete involves very complex relationships. Aside from the variables associated with the mix characteristics, which are substantial, there are several within the roller which affect the compaction, including the: weight of the roller, the vibratory frequency and amplitude, and the dynamic force.

The choice of these variables is crucial to obtaining adequate compaction and a smooth pavement. But as in other areas of advanced technology, the benefits appear to far outweigh the disadvantages. Potentially, vibratory compaction offers higher densities with fewer passes than do static rollers and therefore also offer economy in equipment operation.

STATE OF THE ART

Although two surveys of the use of vibratory compactors on bituminous mixtures have been made fairly recently,[2,3] the use is changing so rapidly it was felt that an up-to-date state of the art report would be worthwhile. Therefore, a questionnaire concerning the specifications governing the use of vibratory rollers on bituminous concrete was composed and sent to the 50 state highway agencies. The questionnaire form showing the total responses is shown in Appendix A. All 50 agencies replied and many indicated that their specifications covering this area of construction were in a state of change.

As for the results of the 49 states that use bituminous concrete base courses only four states prohibit the use of vibratory rollers on them. Of the 45 that permit it, at least 23 require written permission of the engineer and/or satisfactory experimental rolling prior to approval.

However, with the emphasis placed on the smoothness of bituminous concrete surface courses, there is more reluctance to allow vibratory rollers on these surfaces. The prohibition of the use of vibratory rollers on surface courses is enforced by 15 agencies. This prohibition probably is based on the poor early performance alluded to in the Introduction as well as negative intuitive reactions, although it must be admitted that obtaining a satisfactory riding surface with vibratory rollers requires particular attention to roller characteristics and an experienced and conscientious roller operator. At least 17 of the 35 agencies that permit vibratory rollers on surface courses require prior specific written approval or experimental verification of performance.

Many manufacturers make two types of vibratory rollers. One is a dual-drum roller, usually with drive and vibration on both drums, and the other is a single-drum roller with rubber drive wheel(s). There have been occurrences of poor performance with the latter type on surface courses due to tire marks and/or tire pickup.[1] Thus, the survey included question No. 2 to determine how widespread the dissatisfaction with rubber tired vibratory rollers on surface courses might be. Eighty-six percent (30 out of 35) of those permitting vibratory rollers on surface courses allow or, if requested, would allow rubber tired vibratory rollers on surface courses. Interestingly, the New York DOT requires vibratory roller drive wheels to be pneumatic. Many respondents stated that no request for using rubber tired vibratory rollers on surface courses had been made. This subject is discussed in more detail under Field Experience.

As previously mentioned the choice of vibratory roller characteristics is important in obtaining a well compacted, smooth bituminous concrete. Table 1 shows the state agencies that specify a particular characteristic and what that characteristic is.

Table 1

SPECIFIED CHARACTERISTICS OF VIBRATORY ROLLERS
Basic Conversion Units: 1 lb. = .0454 kg
1 in. = .0254 m

State	Weight	Frequency, VPM	Amplitude	Dynamic Force
Idaho	60 lb./in. min.	—	—	250 lb./in. min.
Ill.	—	1,000-1,600	—	23,000 lb. min.
Mass.	—	1,400-1,500	—	—
Mich.	16,000 lb. min.	—	—	—
Nev.	12,000 lb. min.	—	—	—
N.H.	—	—	—	27,000 lb. min.
N.Y.	120 lb./in. min.	1,400-2,400	.035-.100 in.	18,900 lb. min.

As Table 1 might indicate, the New York State DOT has by far the most encompassing specification for vibratory compaction equipment, and therefore this specification is included as Appendix B. In summary, this specification covers the drum width, unit static and dynamic force, frequency, amplitude, and speed, as well as the number of passes of each roller.

The initial reaction of many engineers to using vibratory rollers is to use them only as intermediate rollers; i.e., a steel wheel, pneumatic, or vibratory roller used in a static mode must precede and/or follow the vibratory roller. Thus the reason for the last question in the questionnaire. This practice apparently is not widespread as only six agencies effectively relegate the vibratory rolling to the intermediate stage by requiring static breakdown and finish rolling. It is presumed, although the questionnaire was not so worded as to determine this exactly, that the vibratory roller could be used in the static mode as the breakdown or finish roller, if production allowed.

From the cover letters, comments, and reports accompanying the questionnaire replies, it is apparent that many agencies are taking a critical look at the performance of vibratory rollers and that as the rollers demonstrate their capabilities they are being accepted.

FIELD EXPERIENCE

In reading various reports and talking with many engineers concerning vibratory compaction many impressions have been gained, some published and some just verbalized. Many have a direct bearing on the proper use of and the results obtained with vibratory rollers and in the summaries that follow documentation is provided where available.

On base courses, higher densities with fewer passes have been obtained with vibratory rollers as compared with static rollers of essentially comparable weight.[4] Also vibratory compaction has produced higher densities at the longitudinal joint than has static compaction.

In Virginia, static breakdown rolling has not been required, however, in one case where a 9" (23mm) thick lift was placed, the base was left unrolled for an hour or two so that it could cool sufficiently that the vibratory roller did not cause lateral displacement and excellent density was achieved throughout the entire lift.[5] There are occasions in which tender mixes or high temperatures are encountered that a static breakdown roller or delayed vibratory rolling is advisable.

Dual-Drum Density Vs. Single-Drum Density

It has been found that a dual-drum vibratory roller generally can achieve comparable densities in about half the number of passes as a single-drum vibratory roller. Considering the compactive effort produced by each, this finding should not be surprising. Virginia as well as other states has found that for their production levels (1,000-3,000 tons, 9.0×10^5 - 27.0×10^5 kg per day) a dual-drum vibratory roller can replace two conventional rollers.

Dual-Drum Vs. Rubber-Tired Vibratory Rollers

Controversy surrounds the use of rubber-tired vibratory rollers. The advantages are better traction on grades and the tighter surface appearance produced by the rubber tire. (The latter may or may not be considered an advantage.) Disadvantages are pickup,[1] excessive use of fuel oil to prevent pickup, and or tire marks on the pavement, all of which generally pertain only to surface courses. Attempts to eliminate these problems have included the use of steel wraps over the rubber tires to produce, in effect, a three-wheel, single-drum vibratory roller. At least one manufacturer uses a single, wide (48", 1.2 m) smooth rubber tire as the power drive. This roller seems to perform well without exhibiting any pickup. However, it appears that no clear-cut preference exists as regards the two types of rollers.

Joint Compaction

Although, as previously stated, a higher density can be obtained on longitudinal joints with a vibratory roller the compaction procedure will normally vary from that used with a static roller. When rolling a longitudinal joint with a static roller, the general practice is to "pinch" the joint with a narrow width of the roller on the uncompacted mix; this allows a greater stress to be exerted on the uncompacted mix. This procedure generally will not be satisfactory with a vibratory roller. If the major portion of the roller is on the compacted mix, "chattering" will likely take place. This phenomenon is not only noisy, it is likely to cause ridging, broken aggregate, and lower densities. Therefore, to properly "pinch" the longitudinal joint, the vibratory roller should only slightly overlap onto the compacted mix.

Roller Operator

There is no question that operator skill must be greater for vibratory rollers than for static. On some rollers, the frequency, amplitude, and speed must be matched to produce an acceptable surface and density. Also, with some rollers the vibrations must be cut off prior to stopping or reversing direction. Neglect in the latter case will produce a very poor surface. The previously mentioned change in the procedure of obtaining longitudinal joint compaction must be observed.

Miscellaneous

There has been controversy over whether or not vibratory rollers can cause migration of fines to the surface of the mix. It is quite likely that the interaction of a particular roller with a particular mix can cause asphalt and fines to float to the surface. As long as flushing is not produced, this migration should not be a disadvantage and, in fact, may improve the permeability of the pavement. However, such migration does not seem to be encountered very widely.

REFERENCES

1. Cechetini, James A., and George B. Sherman, "Vibratory Compaction of Asphalt Concrete Pavements," a paper presented at the Association of Asphalt Paving Technologists, February 1974, Williamsburg, Virginia.

2. Geller, M., "Basic Information Concerning Vibratory Compaction of Bituminous Mixtures" Vibro-Plus Products, Inc., April 1971.

3. "Use of Vibratory Rollers for Compacting Asphaltic Concrete," Federal Highway Administration, March 1972.

4. Hughes, C. S., "Virginia Practice," Proceedings, AAPT, February 1970.

5. _______________, and G. W. Maupin, Jr., "Installation Report — Thick Lift Bituminous Base," Virginia Highway & Transportation Research Council, November 1972.

APPENDIX A

QUESTIONNAIRE

Vibratory Compaction of Bituminous Concrete Mixes

1. (A) The use of vibratory rollers for compacting bituminous concrete base courses is:

   4 prohibited

   45 permitted

   0 required

   (B) The use of vibratory rollers for compacting bituminous concrete surface courses is:

   15 prohibited

   35 permitted

   0 required

   Further questions apply only where vibratory rollers are permitted or required.

2. Are rubber-tired vibratory rollers allowed on surface courses? (Pertains to question 1 (B).)

   30 Yes   5 No

3. Are any of the items below specified?

   A. Weight - 4 Yes 0 No   if yes, weight = ________ lbs.

   B. Frequency - 3 Yes 0 No   if yes, frequency = ________ vmp

   C. Amplitude - 1 Yes 0 No   if yes, amplitude = ________ in.

4. Do you require a static roller with the vibratory for

   breakdown rolling? 7 Yes 38 No

   finish rolling? 18 Yes 27 No

Prepared by: ____________________
Title: ____________________

_____ I would like to receive a copy of the final compilation of the results of this questionnaire canvass.

Return to: C. S. Hughes
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P. O. Box 3817, Univ. Stn.
Charlottesville, Va. 22903

APPENDIX B

NEW YORK STATE DOT
SPECIAL NOTE
VIBRATORY COMPACTION OF BITUMINOUS CONCRETE

ALL BASE COURSE AND REGULAR OPEN-GRADED BINDER COURSE:

The contractor may, at his option, substitute one vibratory roller, meeting the requirements herein, in lieu of the conventional three (3) roller compaction train stipulated in the general specifications. Under this option, no other compaction equipment is required.

ALL TOP COURSES AND DENSE GRADED BINDER COURSES:

The contractor may, at his option, substitute one vibratory roller, meeting the requirements herein, in lieu of the breakdown roller only in the conventional compaction train. Under this option the pneumatic tired roller and steel-wheel tandem finish roller, meeting the requirements of the general specifications are required.

One vibratory roller shall be provided for each nominal 12 foot lane of paving. The vibratory rollers shall be of a type that are specifically designed and intended for the compaction of bituminous concrete and shall be approved by the Deputy Chief Engineer, Technical Services, prior to use.

Vibratory rollers shall meet the following requirements:

REQUIREMENTS FOR VIBRATORY ROLLERS
TOP, BINDER, BASE COURSES

Drum Width	84 inch (minimum).
Unit Static Force (at the drum)	120 lbs. per linear inch of drum width (minimum).
Unit Dynamic Force (at the drum)	225 lbs. per linear inch of drum width, computed at operating frequency, (minimum).
Unit Total Applied Force (at the drum)	350 lbs. per linear inch of drum width, computed at operating frequency, (minimum).
Unit Static Force (at the drive wheel)	240 lbs. per linear inch of the drive wheel width (minimum).

REQUIREMENTS FOR VIBRATORY ROLLERS
TOP, BINDER, BASE COURSES
(Continued)

Vibration Frequency	1700-2400 VPM-Top and Binder Courses. 1400 VPM (minimum) - Base Course, all lifts.
Amplitude	.035 inch - .100 inch.

Additional Requirements for the Compaction of Base Courses, all lifts:

Unit Total Applied Force (at the drum)	275 lbs. per linear inch of drum width, computed at 1500 VPM frequency, (minimum).

Vibratory roller drive wheels shall be pneumatic.

If a vibratory compactor is used, the Contractor shall furnish, for the exclusive use of the Engineer, a vibrating reed tachometer. If more than two vibratory rollers are used, one vibrating reed tachometer for each two rollers shall be provided. The vibratory reed tachometer shall have a frequency range of 1000 VPM to 4000 VPM with a minimum reed interval of 50 VPM between 1000 VPM and 2000 VPM, and a minimum reed interval of 100 VPM between 2000 VPM and 4000 VPM.

Rollers shall operate at a uniform rate of speed not to exceed 3 miles per hour.

When vibratory compaction equipment is used, one roller pass shall be defined as a single coverage of the drum over any point of the pavement per direction of roller travel.

Required Number of Passes:

	Vibratory Compaction		Conventional
Pavement Course	Vibrating Passes	Static Passes	Rollers
Base (All Lifts)	4	2	Not required.
Binder (Open-Graded)	3	2	Not required.
Binder (Dense-Graded)	3	2	Pneumatic and finish required*
Top (All Types)	2	2	Pneumatic and finish required*

*The number of passes of the pneumatic and finish roller shall be as required in the General Specifications.

Longitudinal joints shall be compacted by using one of the pneumatic drive wheels to overlap the joint in 2 passes (with the drum operating static). The rolling sequence for the compaction of the longitudinal joint shall be as directed by the Engineer.

To prevent adhesion of the mixture to the drum, the drum shall be kept properly moistened with water, or water mixed with small quantities of detergent. If required to prevent tire pickup, the pneumatic drive wheels may be coated with a fine mist spray of fuel oil. In all instances, the surface of the pavement shall be protected from drippings of fuel oil or any other solvents used in paving, compaction or cleaning operations.

Other general compaction requirements stipulated in the specifications shall remain in effect, as directed by the Engineer.

If, in the judgment of the Engineer, unsatisfactory results are being obtained using this optional compaction procedure, the Contractor shall cease using this procedure and progress the work in accordance with the compaction procedure stipulated in the specifications for these items at no extra cost.