VIBRATORY ROLLER EVALUATION STUDY

(INTERIM REPORT NO. 1)

by

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ABSTRACT

The Louisiana Department of Highways has in progress a two phase program to evaluate the use of vibratory rollers in the compaction of asphaltic concrete pavements. Phase one on the first construction project is now complete with eight (8) different vibratory rollers having participated. Emphasis of the evaluation is centered upon two requirements contained in the Specifications: (1) relative roadway density and (2) surface smoothness. In addition, results obtained with the various vibratory rollers are compared with results produced by conventional rollers and rolling methods.

Findings indicate that vibratory rollers used alone are capable of replacing the three static weight rollers in the compaction process. Overall density and surface smoothness results compared closely with those obtained by conventional rolling methods and were found to meet specification requirements. It was, therefore, recommended and subsequently adopted by the Department that vibratory rollers be permitted as an alternate to conventional rollers on all existing and future construction projects involving the compaction of asphaltic concrete.

IMPLEMENTATION

On the basis of preliminary study findings associated with this particular project, the Department has elected to revise specification requirements regarding compaction and permit the use of vibratory rollers on all State projects involving asphaltic concrete construction. Subsection 501.10 of the Standard Specifications (1)* has been amended to allow the contractor to use whatever machine needed to meet end-result specification requirements (Appendix). Rather than specify method and type of rolling, it was the Departments' feeling that adoption of an end-result philosophy toward compaction of asphaltic concrete would serve the best interests of the Department as well as the contractor. Regardless of the means employed. however, the Department reserves the right to reject poorly performing rollers and require replacement or additional rollers as may be necessary.

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* Numbers in parenthesis refer to list of references on page 30.

INTRODUCTION

Construction of hot mix asphaltic concrete (HMAC) pavements was introduced to Louisiana during the late 1940's and has since grown to be one of the State's leading industries. Although quality materials are necessary to produce a good pavement, one of the most important considerations in obtaining a quality end product is placement and compaction of the mix on the roadway surface. A well compacted mixture provides the user with smooth riding surface on which to travel and will withstand repeated loadings for a long period of time.

First generation compaction equipment consisted of steel-wheel rollers that varied considerably in size and weight. It was later determined that greater compactive effort was needed during construction to reduce pavement rutting or displacement of the mixture under traffic. This led to development and use of the pneumatic tire roller as an intermediate compaction device. Louisiana, like most other states, subsequently adopted specifications requiring the use of three rollers to be used sequentially in the compaction of HMAC. These rollers which consist of the three wheel, pnenumatic tire, and steel wheel are required to perform breakdown, intermediate and finish rolling respectively. Although satisfactory results are produced by this method of rolling, the process is both time consuming and uneconomical. Costs have risen considerably during recent years due to sizeable increases in prices for fuel and labor. Any reduction in these costs would result in a savings to the contractor and in turn, the Department.

Vibratory rollers are now being marketed throughout the United States as a possible replacement for the three conventional rollers mentioned previously. Similar to other types of compaction equipment, they are available in a wide range of weights and sizes. As a general rule, the rollers are self-propelled and employ the use of rotating eccentric shafts or weights to produce a dynamic force in addition to its static weight. This enables the machine to impart more compactive effort per pass when compared to static weight rollers. By allowing for fewer passes, production can be increased to the extent that one roller will often be sufficient to do the entire job.

Although vibratory compaction of asphaltic concrete has been somewhat limited to date, most state highway departments and other industry personnel have had some experience in their use. An inquiry published by the Federal Highway Administration in 1972 (2) indicated that with 33 states reporting, approximately two-thirds found that pavements compacted with vibratory rollers were equal to or better than those rolled with conventional static weight rollers. In a more recent study by the State of California (3). it was concluded that several of the vibratory rollers evaluated were capable of producing results within state compaction requirements.

Previous experience by the Louisiana Department of Highways includes an evaluation of the Ray Go Rustler 404 vibratory roller on a typical construction project in 1971 (4). Although this particular evaluation was not extensive, it was determined that roadway density and surface smoothness obtained with the vibratory roller compared closely with that produced by conventional rollers. This prompted the recommendation at that time that a more comprehensive study be undertaken to investigate the feasibility of allowing the use of vibratory rollers as an alternate to the three static weight rollers required by specifications.

Subsequent to this period, Louisiana has adopted specifications calling for "end result" acceptance of HMAC pavements (1). Included are specified limits for relative roadway densities as well as percent of roadway out of surface tolerance. Densities are determined from roadway cores while a ten foot (3.0 m) rolling straightedge is used to measure longitudinal tolerance for acceptance purposes. These "end result" criteria are based on previous data obtained from pavements compacted by conventional methods and contain statistically based limits for full contract payment. Penalties are assessed when measured densities and/or surface tolerance results fail to meet the predetermined acceptance limits.

In order for any roller or group of rollers to qualify under these specifications, they must be capable of producing repeated results that equal or exceed specified density and surface smoothness values. Consequently, any evaluation program to determine adequacy of compaction equipment must be designed not only to answer questions related to individual roller performance but to compare results obtained with specification requirements and results produced by currently specified standard equipment. This, in summary, is the purpose of this study.

SCOPE

This study is a performance evaluation employing the use of eight (8) different vibratory rollers in addition to conventional static weight equipment to compact asphaltic concrete pavements. The entire evaluation centers upon results obtained from field construction methods and practices. Attempts are made to determine if vibratory rollers used alone can take the place of equipment currently required to perform breakdown, intermediate and finish rolling respectively.

METHOD OF PROCEDURE

In order to determine the adequacy of vibratory rollers in compacting asphaltic concrete, a comprehensive field evaluation program was decided upon. Two construction projects were designated as experimental and special provisions were prepared requiring the contractor to permit various vibratory rollers to compact the mix after laydown. Adjustments were made in "end-result" specificiation requirement to compensate for any problems that could be attributed to rolling.

The first of these two projects was recently completed and is the subject of this report. It consisted of an asphaltic concrete overlay on an existing two lane surface treatment roadway, State Route La. 19 near Baton Rouge. The old surface was constructed on a sand-gavel base with open ditch drainage on both sides. The overlay involved the placement of a two inch binder and a one and one-half inch wearing course meeting standard specifications for a Type 1 mixture (Appendix). In all, data was taken for some ten miles of highway and will be discussed in some detail later. The second experimental project will involve the placement of base as well as binder and wearing courses; however, it is not expected to begin until fall of 1974.

Invitations to participate in the experimental evaluation were extended to all manufacturers of vibratory rollers who market their machines in Louisiana. In all, eight accepted and were included in the evaluation program along with the contractor's three conventional rollers as indicated previously. Since this was primairly a performance evaluation, each manufacturer was asked to furnish the type rollers he felt would do the best job. Rather than stipulate the method and type of machine to be used, the decision was made to leave this entirely to the manufacturer's discretion. He should be best familiar with the operation and capabilities of his machine and such an approach would eleminate a number of study variables that would serve to extend the scope beyond reasonable bounds. Factors such as roller weight and speed, vibration frequency and amplitude, and number of passes were pre-determined by each manufacturer and although recorded, they were not introduced as study variables.

A wide variety of rollers were selected by the various manufacturers for use on the project. All, however, conformed to one of the following three catagories:

(1) *steel wheel propelled*, (2) *rubber tire propelled and* (3) *tandem or double drum*. These are shown in Figures 1, 2 and 3 respectively. Each roller used was self-propelled and employed rotating eccentric shafts or offset weights for vibration purposes. Table 1 lists these and other specifications applicable to each given roller.

In order to facilitate adequate collection of data, the experimental project was subdivided into test sections of approximately one mile (1.6 km) in length. Each roller producer was allowed to use the first few hundred feet to adjust his machine. Most employed the use of density - growth curves to determine the method of rolling while some chose to compact the mix by pre-determined means. The Department maintained the use of a nuclear density device throughout the project for periodic measurements which were available for manufacturers use upon request. Once rolling patterns, speed, vibration frequency and amplitude were established, the roller compacted the mix in the usual manner until the test section was finished. This same procedure was followed for both the binder and wearing courses. The contractor paved in such a sequence as to allow one roller to finish its test section before proceding on to another.

In addition to nuclear density measurements, the Department sampled and recorded numerous other data during construction. Included are mix temperatures at the asphalt plant and on the roadway, ambient temperatures, rolling times, number of passes, relative compaction determined from roadway cores and surface tolerances determined from 3 (.9 m), 10 (3.0 m), 12 (3.7 m) and 15 (4.6 m) foot traveling straightedges.

Plant production reports were continuously monitored and recorded for any fluctuations in materials characteristics and quality. Complete summaries of this data for both the binder and wearing courses are given in the Appendix. Statistical analysis of this data will also be discussed later in the report.

In order to further quantify surface quality in terms of smoothness, is was decided to evaluate the various test sections with a Mays ride meter[1]. Roughness measurements were made immediately after the completion of each course for individual analysis as well as relative comparisons. This means of quantifying ride quality

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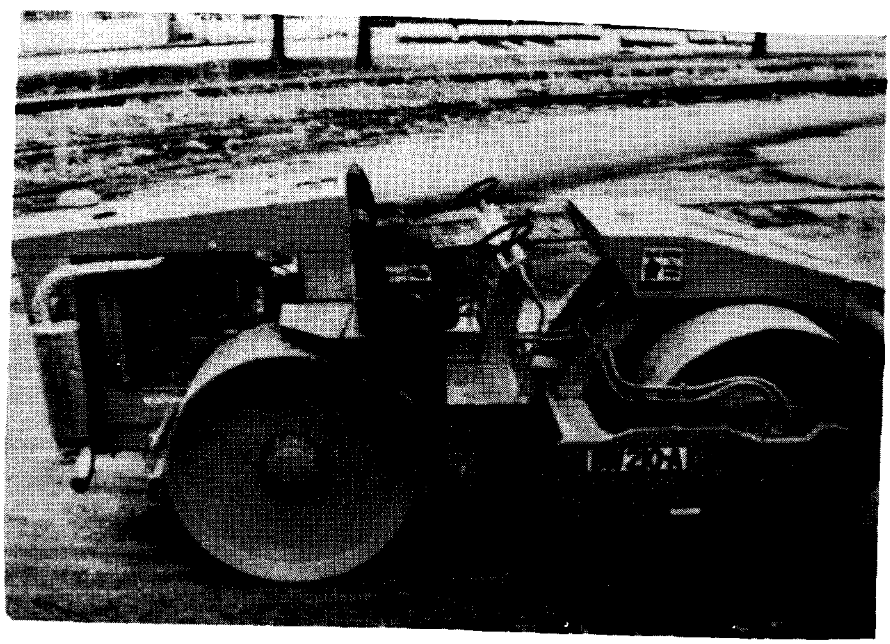
1 - Instrument for detecting pavement roughness.

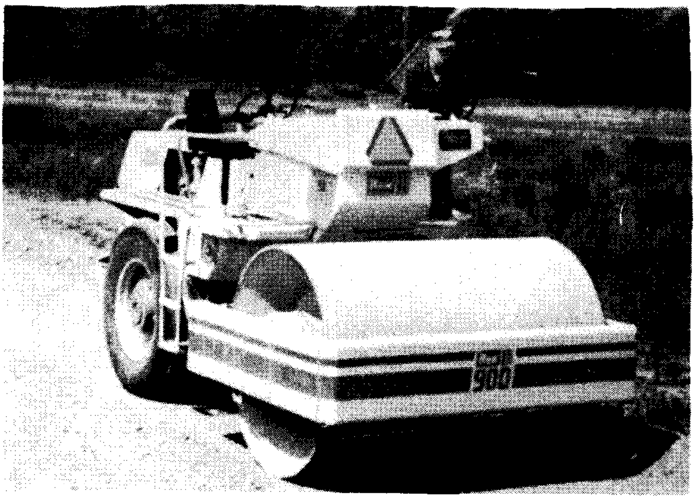
BROS SWV-735SV



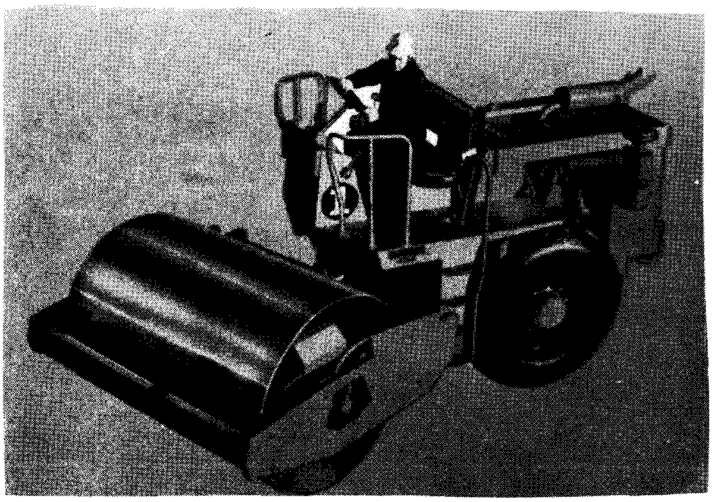
BUFFALO BOMAG BW-210A

STEEL WHEEL VIBRATORY ROLLERS

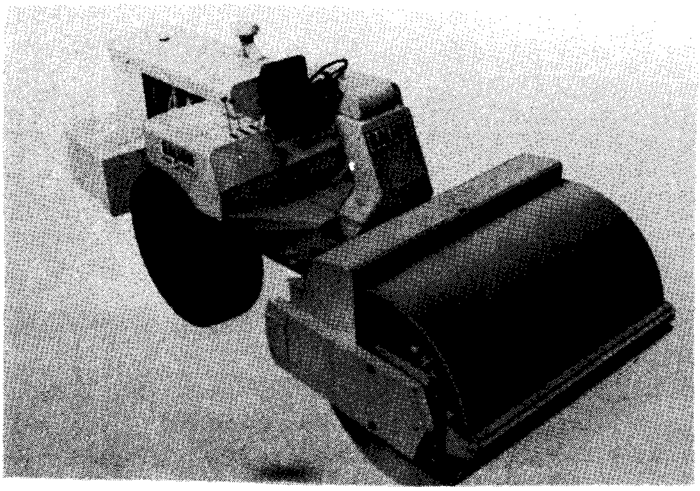
FIGURE 1



REX SP-900



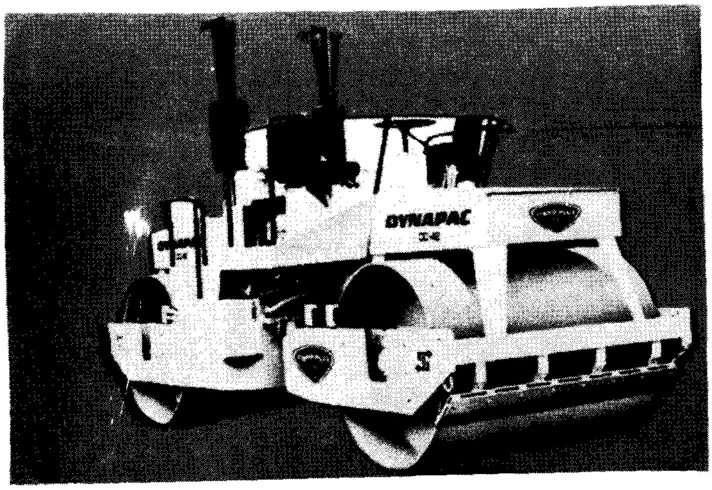
RAYGO RUSTLER 404-B



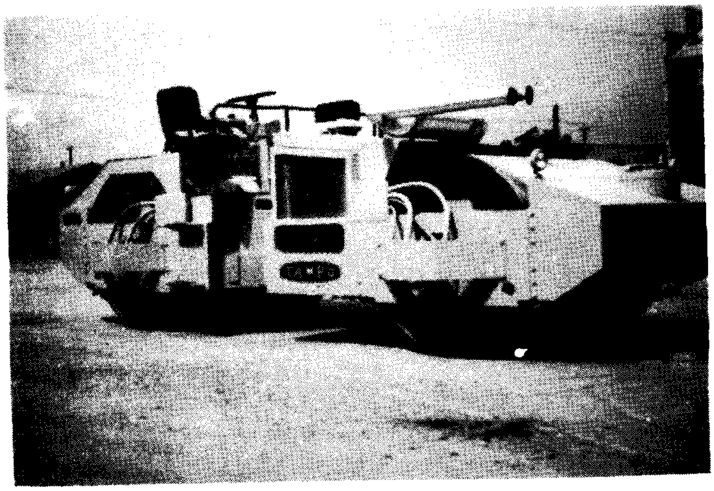
GALION VOS-84

RUBBER TIRE VIBRATORY ROLLERS

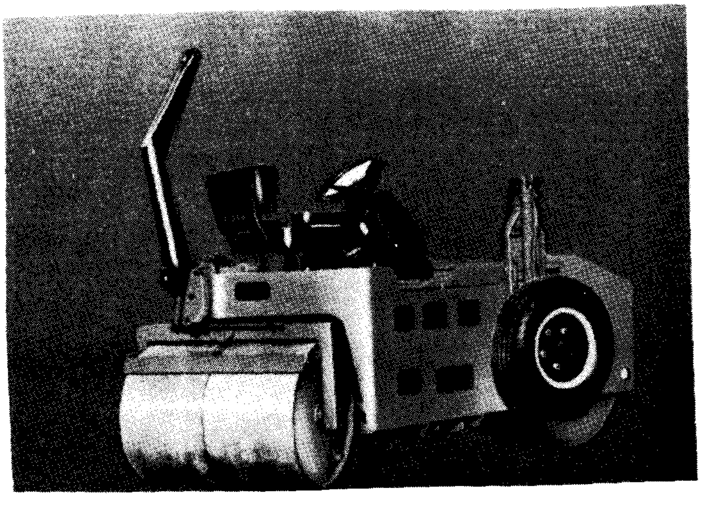
FIGURE 2



DYNAPAC CC-42A



TAMPO 166A



ESSICK VR42RE

TANDEM OR DOUBLE DRUM VIBRATORY ROLLERS

FIGURE 3

TABLE 1

VIBRATORY ROLLER DESCRIPTIONS

	REX SP - 900	BROS SWV - 735 SV	RAY GO RUSTLER 404 - B	DYNAPAC CC 42A	BUFFALO BOMAG BW - 210A	GALION VOS - 84	TAMPO 166A	ESSICK VR42RE
Roller Type	Rubber Tire	Steel Wheel	Rubber Tire	Double Drum	Steel Wheel	Rubber Tire	Double Drum	Double Drum
Manufacturer	Rexnord, Inc.	American Hoist & Derrick Co.	Raygo Inc.	Vibro-Plus Products, Inc.	Koehring Road Div.	Galion Mfg. Co.	Tampo Mfg. Co.	Essick Mfg. Co.
Dimensions								
Length (ft.-in.)	18-3	17-11	16-11.5	16-5	16-11.5	18-9.5	17-4.5	9-3.5
Width (ft.-in.)	7-11.5	8-5	7-11.5	6-6.5	7-7	7-10	6-10.5	4-3
Height (ft.-in.)	8-7	7-8	8.5	10-4	7-2	7-10.5	6-5	5-9
Weight (lbs.)	17,900	21,500	18,300	23,000	18,500	20,900	19,200	4525
Drum Diameter (in.)	60	60	59	48	59	60	48	30
Drum Length (in.)	84	84	84	66	84	84	66	42
Turning Radius (ft.-in.)	22-0	17-0	20-5	14-0	16-10	16-10	19-1	12-0
Wheel Base (ft.-in.)	9-4	9-7	9-0	11-4	9-0	9-0	10-4	6-4.3
Curb Clearance (in.)	—	—	15.5	14.5	15.5	18	—	—
Power Plant								
Engine	GMC 3-53	GMC 3-53	DD 3-53	Cat D3145	GMC 4-53	ICH Diesel	GMC 3-53	Wis. VH4D
Electrical (volts.)	12	12	12	12	12	12	12	12
Fuel Capacity (gal.)	55	30	50	60	44	60	35	18
Propulsion System								
Speed (mph)	0-15.5	0-17	0-17.5	0-7.0	0-15	0-15	0-6.75	0-4.5
Tires	16.9 x 30	26 x 56 (steel)	16.9 x 30	—	26 x 56 (steel)	14 x 24	—	—
Vibration System								
Dynamic Force (lbs.)	33,500	35,000	27,000	44,000	42,000	36,000	32,000	10,000
Frequency (vpm)	0-2000	900-1700	1200-2300	2400	1100-2500	1100-1800	0-2500	3450
Water System (gal.)	190	170	—	—	—	175	—	80
Front	—	—	168	115	150	—	165	—
Rear	—	—	15	115	40	—	165	—

is currently being used by the Department as a criterion for rating pavement smoothness.

Data collection was supplemented by daily observations along with visual inspections of the various roadway test sections upon completion of each course of hot mix. These field notes are considered to be an important part of the evaluation since much of the performance of each roller is visual and not easily quantified.

DISCUSSION OF RESULTS

In evaluating the effectiveness of vibratory rollers to compact asphaltic concrete pavements, two criteria must be considered. First, compacted density of the mix being installed is important since this is the best overall means of measuring compactive effort or total applied force produced by the rollers. Secondly, the smoothness and appearance of the finished product are primary considerations in determining ride quality of the pavement. In order for a pavement to serve its intended purpose, is it necessary that it provide a surface conducive to safe and efficient travel. The following, therefore, is a discussion of these areas as determined by findings on the first construction project.

PAVEMENT DENSITIES

For purposes of this discussion, relative densities are expressed in terms of percent laboratory briquette. Pavement densities were determined from roadway cores taken 24 hours after compaction and laboratory briquette densities were measured from 75 blow Marshall specimens prepared from plant samples on the day the mix was produced. This measure of relative compaction is the basis for acceptance under Department of Highways specifications. A minimum value of 95 percent relative density is required for full payment and lower values are penalized according to a statistically based schedule.

Average relative densities for the various individual test sections are listed in Tables 2 and 3. The average number of passes required from each roller or group of rollers used on both the binder and wearing courses are also shown. Although density growth relationships for each type roller were not developed during this study, it can be noted that vibratory compaction equipment obtained higher pavement densities with fewer passes than static weight rollers. Depending upon the type of vibratory roller used, the number of passes required for each compacted section ranged from 7 to 13. Static rolling normally required more than twice this total number of passes.

In order to facilitate visual comparison of relative densities obtained by each of the rollers, Figure 4 was prepared. Considerable variability in density results is

TABLE 2

SUMMARY OF DATA
BINDER COURSE

Roller Name and Class	Number of Passes	Relative Avg. Density (% Lab. Briquette)	Standard Dev. of Relative Densities (% Lab. Briquette)	Linear % of * Roadway out of 1/8 in. Tolerance	Mays Roughness (Inches per mile)
Rex SP-900 (Rubber Tire)	11V	96.2	.94	.51	84.3
Control 1 (3-Conv. Rollers)	3-Wheel-3 Rubber Tire-20 Tandem-3	97.3	.94	.64	77.1
Bros SWV-735 SV (Steel Wheel)	9V	96.3	1.03	.61	71.3
Ray Go Rustler 404-B (Rubber Tire)	11V	96.5	1.65	.83	91.6
Dynapac CC42A (Double Drum)	9 to 13V	94.4	1.50	1.19	95.0
Buffalo Bomag BW-210A (Steel Wheel)	9V	94.5	1.05	.72	75.0
Control 2 (3-Conv. Rollers)	3-Wheel-3 Rubber Tire-20 Tandem-3	96.8	.46	1.29	85.4
Galion VOS-84 (Rubber Tire)	7V	95.6	.93	1.81	106.4
Tampo 166A (Double Drum)	9V	96.6	.83	.50	76.7
Control 3 (3-Conv. Rollers)	3-Wheel-3 Rubber Tire-20 Tandem-3	97.3	1.13	.80	85.8

V = Vibratory Compaction

* - Determined by a 10 foot Rolling Straightedge.

TABLE 3

SUMMARY OF DATA
WEARING COURSE

Roller Name and Class	Number of Passes	Average Rolling Time & Dist.	Avg. Relative Density (% Lab. Briquette)	Standard Dev. Relative Den. (% Lab. Briq.)	Linear % of Roadway Out-of 1/8 in. Tolerance	Mays Roughness (in. per mi)
Rex SP-900 (Rubber Tire)	6V-3S	8.3 min. (230 ft.)	94.8	1.66	.81	90.9
Control (1) (3-Conventional Rollers)	3-Wheel-3 Rubber Tire-9 Tandem-5	13.5 min. (300 ft.)	96.3	1.16	.21	59.1
Bros SWV-735SV (Steel Wheel)	5V	8.3 min. (500 ft.)	96.0	1.08	.06	55.0
Ray Go Rustler 404-B (Rubber Tire)	5V	11 min. (400 ft.)	96.3	.89	.40	67.5
Dynapac CC42A (Double Drum)	6V-1S	9.3 min. (300 ft.)	95.6	1.01	1.53	81.6
Buffalo Bomag BW210A (Steel Wheel)	7V	6.0 min. (270 ft.)	97.0	.82	.32	62.1
Control (2) (3-Conventional Rollers)	3-Wheel-3 Rubber Tire-9 Tandem-5	Same as Control (1)	95.9	1.12	.57	74.1
Tampo 166A (Double Drum)	7V	6.3 min. (400 ft.)	95.5	.74	.24	61.5
*Essick VR42RE (Double Drum)	18V	123 ft.	95.4	.43	--	115.9

* Machine was too small to maintain pace of the paver. It is being evaluated for small amounts of hot mix compaction, i.e. shoulder work, patching and turnouts.

V = Vibratory Compaction

S = Static Compaction

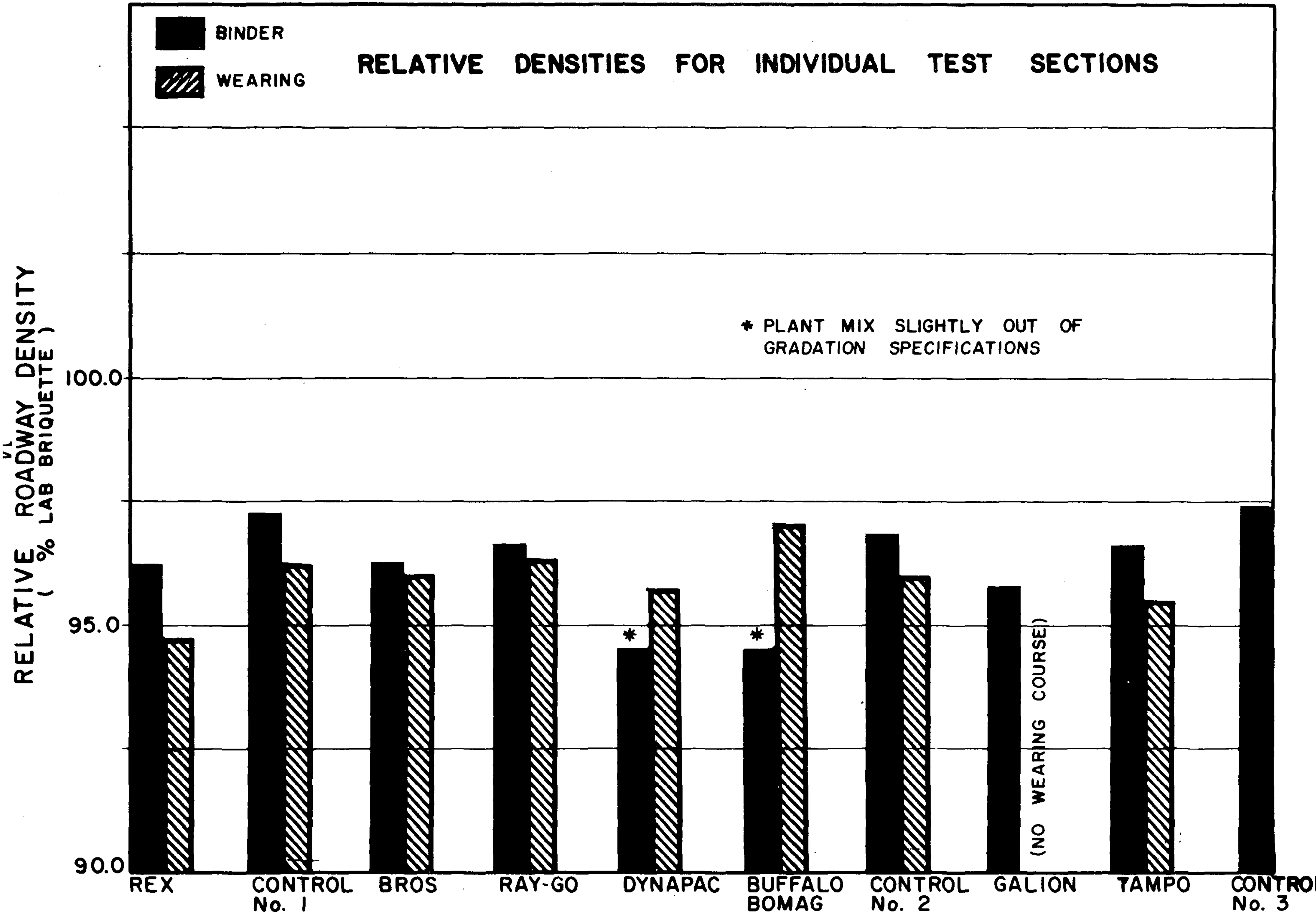

BINDER
WEARING
RELATIVE DENSITIES FOR INDIVIDUAL TEST SECTIONS
RELATIVE ROADWAY DENSITY
(% LAB BRIQUETTE)
100.0
95.0
90.0
* PLANT MIX SLIGHTLY OUT OF GRADATION SPECIFICATIONS
(NO WEARING COURSE)
REX
CONTROL No. 1
BROS
RAY-GO
DYNAPAC
BUFFALO BOMAG
CONTROL No. 2
GALION
TAMPO
CONTROL No. 3

FIGURE 4

not only evident between the different types of rollers but can also be noted for several of the individual rollers between binder and wearing courses. All except two of the rollers yielded higher roadway densities on the thicker lift binder course. These other two rollers encountered some difficulty in meeting required 95 percent compaction on the binder course. On these particular dates, however, the mix produced was slightly out of gradation specifications with excessive fine material which could account for some of the problem.

An attempt was later made to determine if any significant relationship could be found between roadway densities and percentages of material passing the Number 4 and Number 40 U. S. sieves. This attempt proved fruitless yielding correlation coefficients well below the level needed to establish a significant relationship.

Results given in Figure 4 do suggest that roadway densities obtained with vibratory rollers generally compare closely with those produced with conventional equipment. Slightly more consistency in results is produced by three control or conventionally compacted test sections. Even though vibratory rollers yielded densities greater than static rolling in a few cases, overall their performance was at best equal to conventional rollers.

Another important consideration in pavement densities is variability within a given test section. Averages do not always represent a true picture and when viewed alone can be misleading. For this reason, the data were analyzed for statistical properties. Standard deviations which are a measure of variability are listed in Table 2 and are shown graphically in Figure 5. As was the case with roadway density values, considerable fluctuation among the various test sections is apparent. Control or static test sections exhibit data variability that is somewhat more consistent but overall is about average when compared to results obtained with vibratory rollers. Excessively high standard deviations are more predominent in those test sections where low roadway densities were measured. This adds support to the minimum compaction requirements contained in the specifications.

It is significant to note that considerably different standard deviations are not only evident among the different types of rolling but are noticeable between the different courses for each roller. This along with variable density results suggests that operation of the roller itself is an important consideration. In several

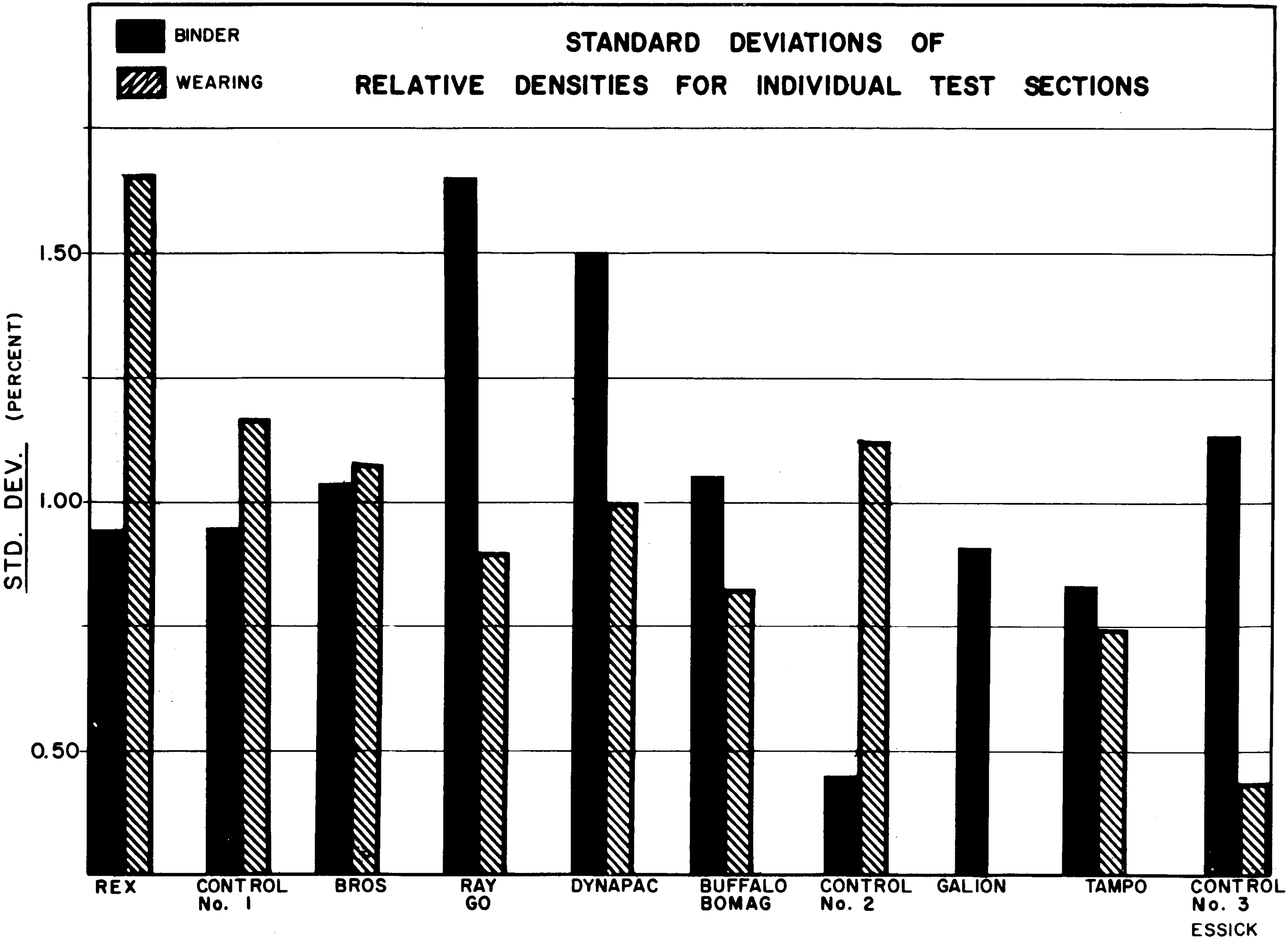

BINDER
WEARING
STANDARD DEVIATIONS OF
RELATIVE DENSITIES FOR INDIVIDUAL TEST SECTIONS
STD. DEV. (PERCENT)
1.50
1.00
0.50
REX
CONTROL No. 1
BROS
RAY GO
DYNAPAC
BUFFALO BOMAG
CONTROL No. 2
GALION
TAMPO
CONTROL No. 3 ESSICK

FIGURE 5

instances with the vibratory rollers, a different operator was used on the wearing course as opposed to the binder. The importance of having an experienced operator control the roller not only is substantiated by data taken on this project but was clearly demonstrated by performance and pavement appearance in the field.

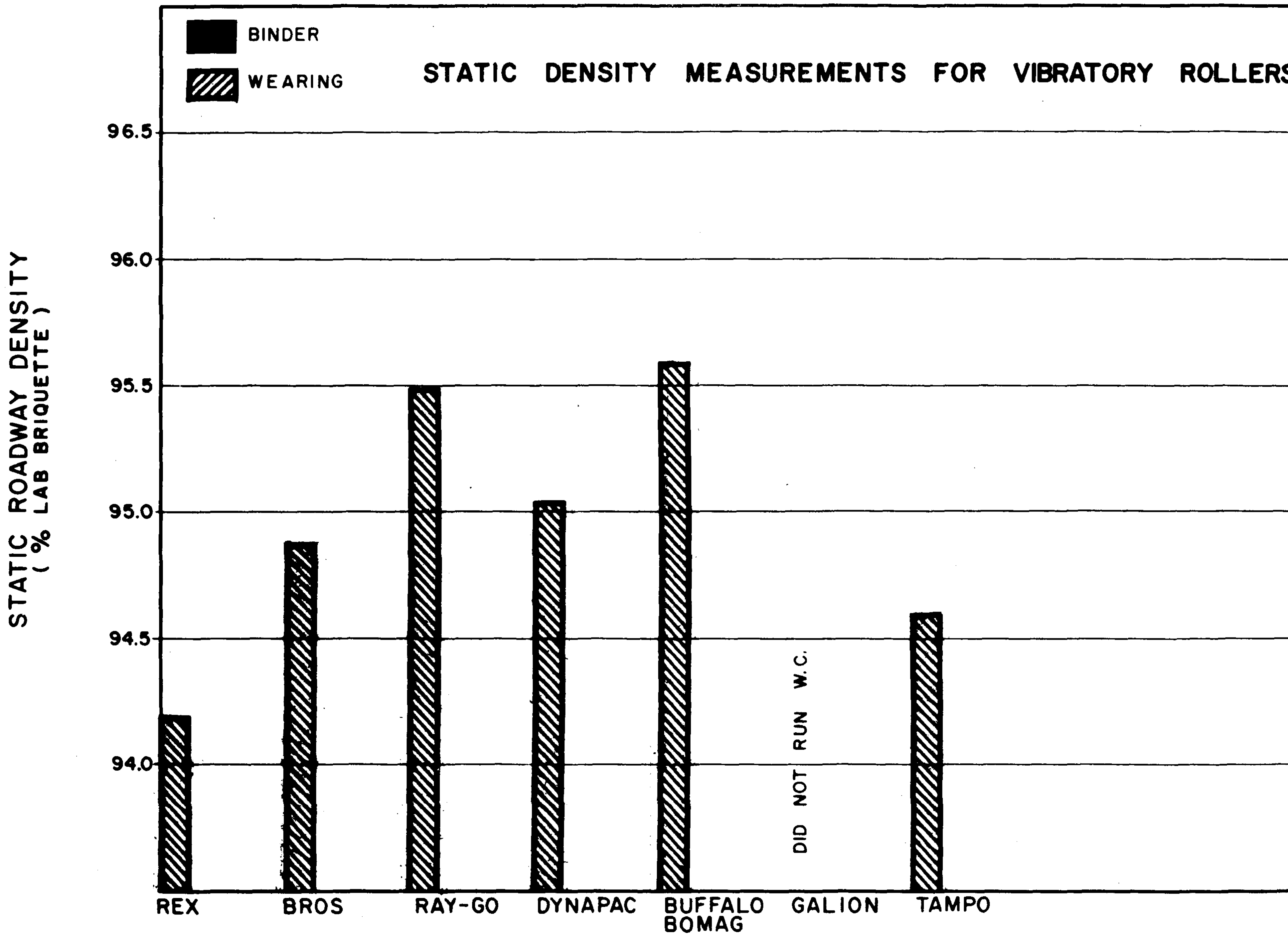
There has been some speculation by different individuals in asphalt paving technology that vibratory rollers are capable of producing required field densities operating in a static mode. To investigate this, each roller operator was asked to turn his vibrating mechanism off and compact an approximate 300 foot section on the wearing course. Findings of resulting relative density measurements are shown in Figure 6. On this particular project, results indicate that static compaction is not as effective as vibratory compaction. Fifty percent of those rollers tried failed to meet or exceed 95 percent relative compaction requirements.

Since the main interest of this study was not to compare individual rollers but gain insight to the effectiveness of vibratory compaction, it was decided to group the data into four roller types for analysis. These roller groups as mentioned previously consist of three vibratory (rubber tire, steel wheel and double drum) along with conventional rolling. Figure 7 shows graphically the results obtained from these groupings of relative densities.

Inspection of Figure 7 reveals that all four general classifications of rollers were able to meet or exceed the 95 percent relative compaction requirement. While control or conventional rolling resulted in slightly higher average densities than did vibratory rolling, overall the various methods compare favorably. In addition, it could hardly be surmized from these comparisions that any one type of roller produced repeated densities that were significantly better than any of the others. This is considered as sound basis for the conclusion that compaction of asphaltic concrete overlays with vibratory rollers is comparable to compaction obtained with the three conventional rollers.

SURFACE SMOOTHNESS

In addition to roadway density, end result specifications adopted by the Department require that the pavement surface meet certain tolerances. The current method of



STATIC DENSITY MEASUREMENTS FOR VIBRATORY ROLLERS
BINDER
WEARING
STATIC ROADWAY DENSITY
(% LAB BRIQUETTE)
96.5
96.0
95.5
95.0
94.5
94.0
REX
BROS
RAY-GO
DYNAPAC
BUFFALO BOMAG
GALION
TAMPO
DID NOT RUN W.C.

FIGURE 6

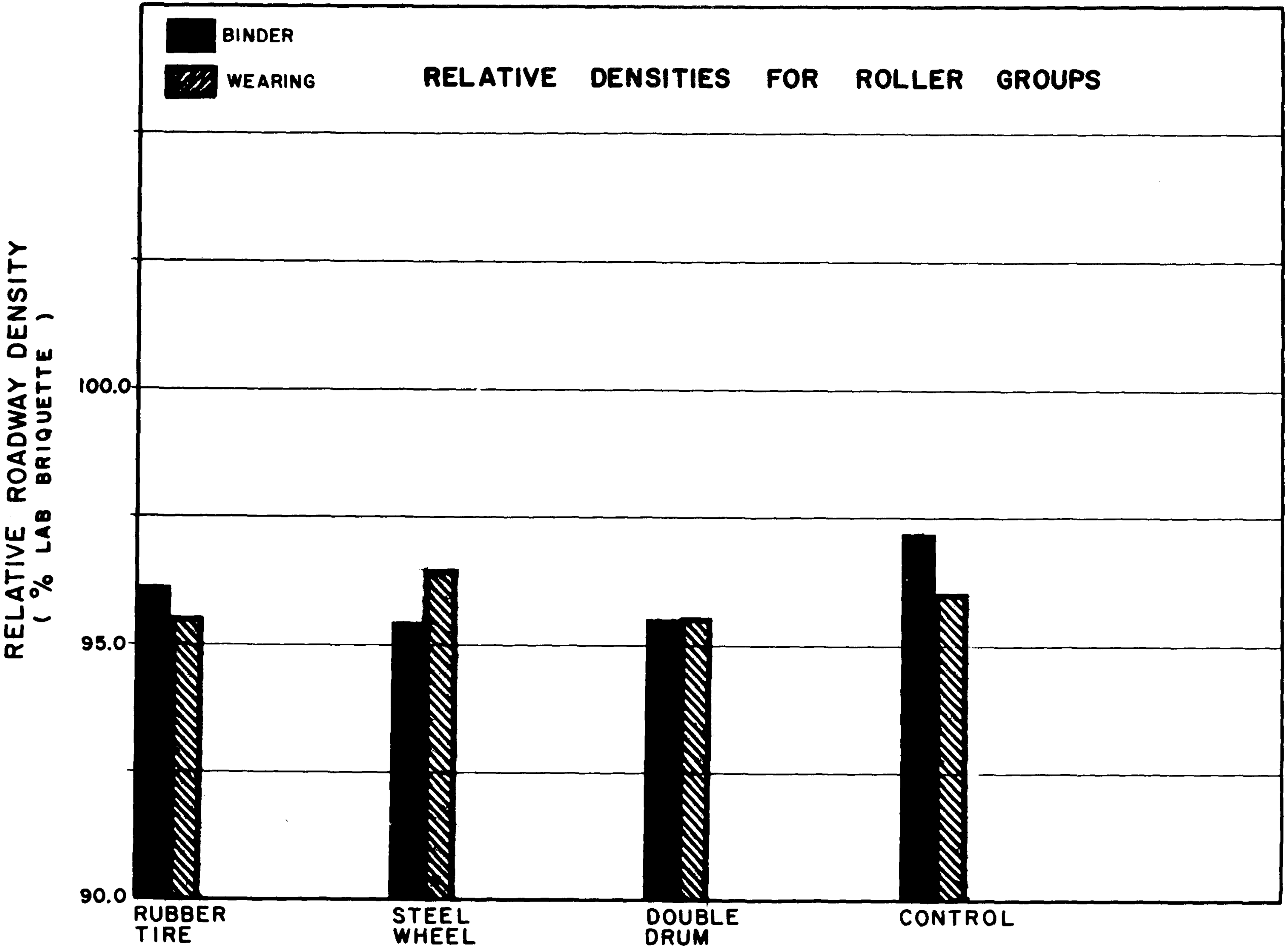

BINDER
WEARING
RELATIVE DENSITIES FOR ROLLER GROUPS
RELATIVE ROADWAY DENSITY
(% LAB BRIQUETTE)
100.0
95.0
90.0
RUBBER TIRE
STEEL WHEEL
DOUBLE DRUM
CONTROL

FIGURE 7

measurement for acceptance is the ten foot (3.0 m) rolling straightedge which has the capability of indicating sections of pavement that exceed a given tolerance over a ten foot (3.0 m) interval. The percent of roadway out of tolerance can then be calculated and compared to specifications. Although control tolerances are specified for the binder course, acceptance testing is required only on the wearing course.

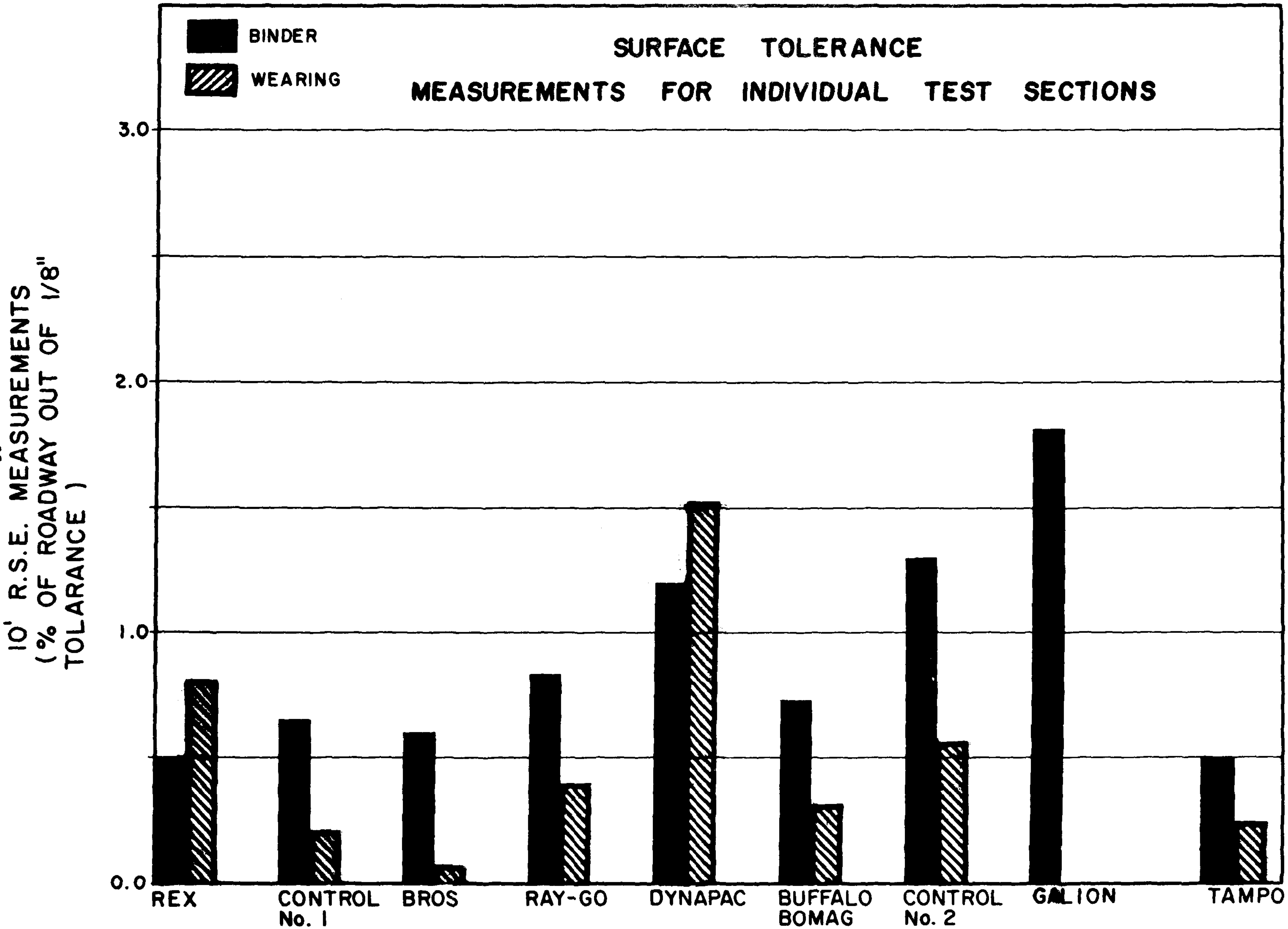
For the type mix and application used in this project, allowable tolerances of 1/4 inch (6.3 mm) and 1/8 inch (3.2 mm) are required for the binder and wearing course respectively. Due to insufficent readings obtained with a 1/4 inch (6.3 mm) tolerance on the binder course, it was decided to use the 1/8 inch (3.2 mm) tolerance on both surface applications for purposes of this evaluation.

The percentage of linear roadway exceeding the specified tolerance for each of the experimental sections is shown in Figure 8. This allows visual comparison of the relative smoothnesses produced by each of the rolling methods as well as improvements or adverse effects obtained between the two lifts. It should be kept in mind that end result requirements for 100 percent payment are based on a maximum of one percent of linear roadway exceeding surface tolerance (wearing course only).

By examination of Figure 8, it can be seen that all except one of the vibratory rollers produced wearing surfaces within tolerance limits. No physical explanation can be given for this one failure since the roller was similar to others that achieved good results and the mix appeared normal in all respects. As mentioned previously, operation of the machine itself is often the determining factor in a well compacted pavement and could have been the basis for problems in this particular instance.

In addition to the ten foot (3.0 m) straightedge, measurements were also taken with the 15 foot (4.6 m) rolling straightedge and are listed in the Appendix. Although only the ten foot measurements are analyzed for discussion of smoothness, it is worthy to note that other straightedge readings appear to produce similar results.

An attempt was made during the early stages of the project to measure transverse tolerances using the three foot (.9 m) straightedge. The purpose of this was to quantify any pavement rutting that might be induced by the various rollers. Measurements taken were negligible and the process was discontinued during



SURFACE TOLERANCE
MEASUREMENTS FOR INDIVIDUAL TEST SECTIONS
BINDER
WEARING
10' R.S.E. MEASUREMENTS
(% OF ROADWAY OUT OF 1/8" TOLARANCE)
3.0
2.0
1.0
0.0
REX
CONTROL No. 1
BROS
RAY-GO
DYNAPAC
BUFFALO BOMAG
CONTROL No. 2
GALION
TAMPO

FIGURE 8

application of the binder course. Attempts to measure transverse depressions in the pavement with a ten foot (3.0 m) wooden straightedge also proved fruitless suggesting that rutting by the various rollers is insignificant.

Another method used by the Department to evaluate pavement smoothness is the May's Roughometer. This device is designed to attach to a standard passenger vehicle and give an indication of pavement roughness at a given speed. Readings are usually expressed in inches of deflection per mile of roadway transversed and for purposes of this discussion are listed at a 40 mph (64.4 km/hr.) speed for each experimental section (Tables 2 and 3). Lower readings characterize smooth pavements while conversely, higher readings reflect rough pavements.

Bar charts showing May's roughness measurements for each individual roller and each roller group are given in Figures 9 and 10 respectively. The data for individual rollers encompass a rather wide range indicating that some produce significantly better results than others. In almost all cases, however, smoother surfaces are indicated for wearing courses than for binder courses which is to be expected. Marked improvements are evident for some while in one instance, the wearing course was found to possess a greater roughness than the binder course.

The Department uses the following May's roughness classification as a guide in rating various asphaltic concrete pavement for ride quality.

Table 4

May's Roughness		Rating
0 - 64	----------------------------------	Very Good
65 - 96	----------------------------------	Good
97 - 169	----------------------------------	Fair
161 - 230	----------------------------------	Poor
230^+	----------------------------------	Very Poor

By inspection of Figure 9, it can be seen that all except one of the wearing course sections rate as good or very good. It can also be noted that on the average, vibratory rolled sections compare favorably with those compacted with conventional equipment.

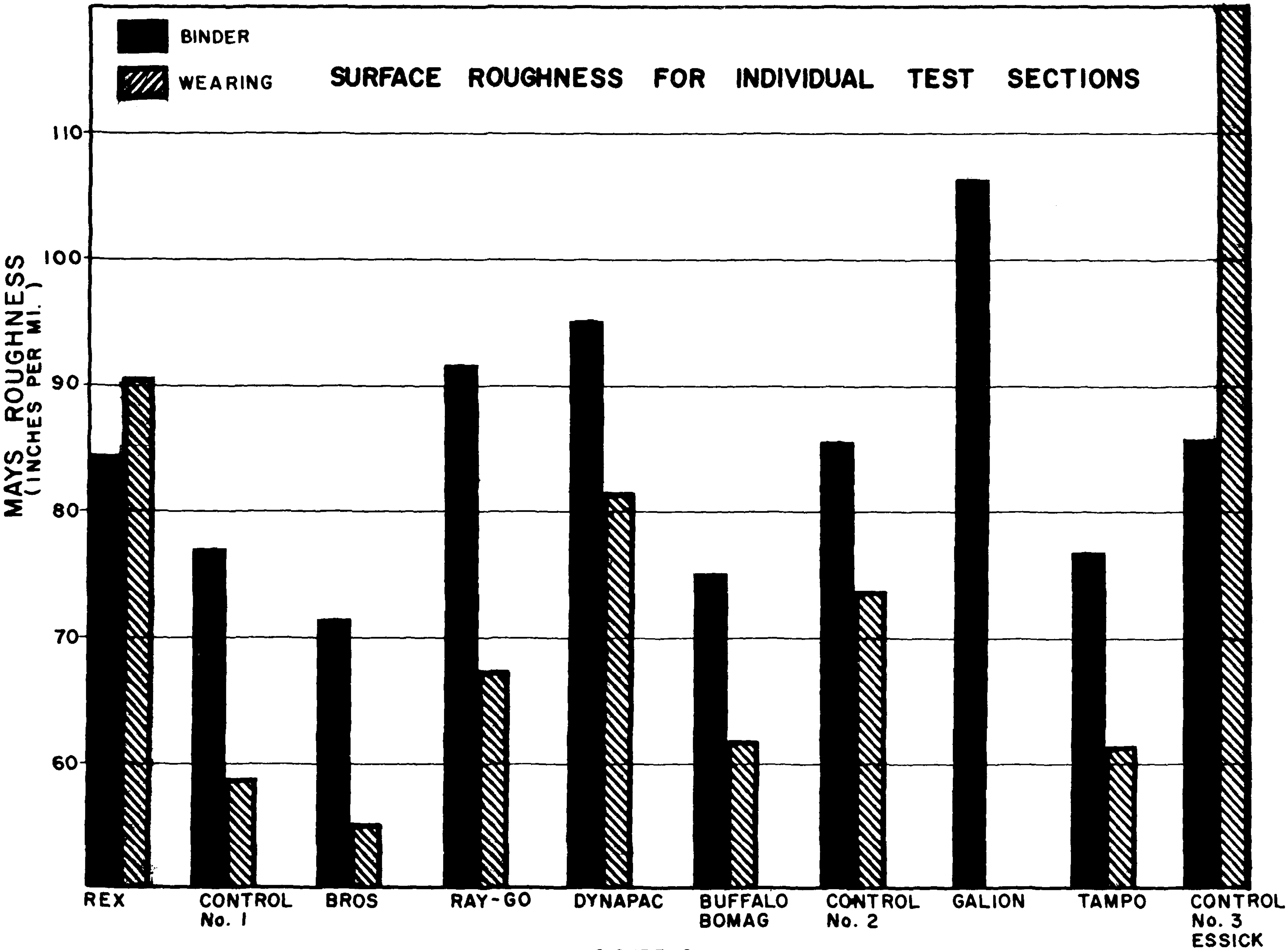

BINDER
WEARING
SURFACE ROUGHNESS FOR INDIVIDUAL TEST SECTIONS
MAYS ROUGHNESS (INCHES PER MI.)
110
100
90
80
70
60
REX
CONTROL No. 1
BROS
RAY-GO
DYNAPAC
BUFFALO BOMAG
CONTROL No. 2
GALION
TAMPO
CONTROL No. 3 ESSICK

FIGURE 9

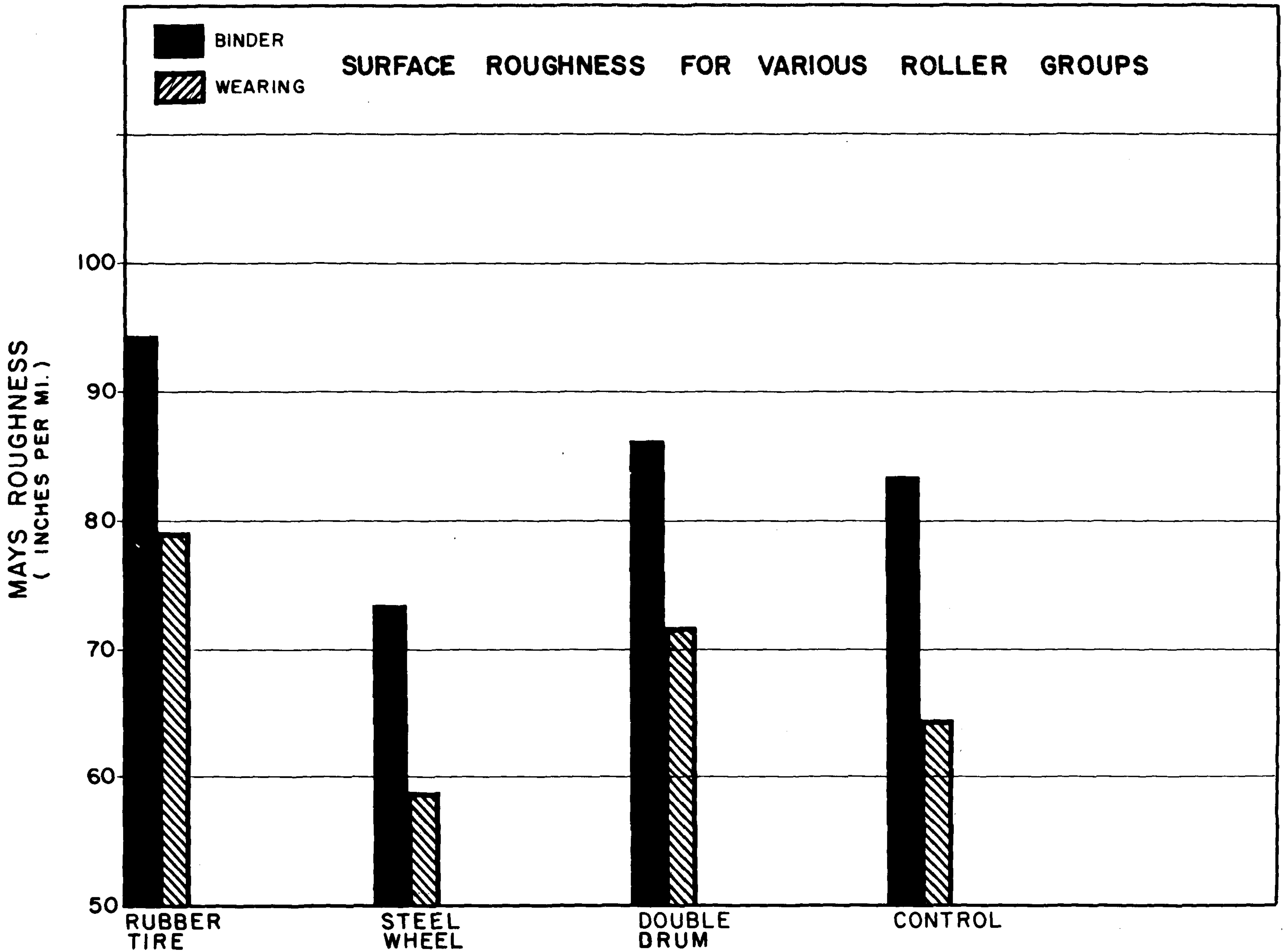

BINDER
WEARING
SURFACE ROUGHNESS FOR VARIOUS ROLLER GROUPS
MAYS ROUGHNESS
(INCHES PER MI.)
100
90
80
70
60
50
RUBBER TIRE
STEEL WHEEL
DOUBLE DRUM
CONTROL

FIGURE 10

Comparison of pavement smoothness measurements obtained with vibratory versus conventional rollers is best illustrated in Figure 10. Control or conventional rollers are about average for the results listed for vibratory rollers. Steel wheel propelled rollers appear to produce best results while rubber tire driven rollers produced slightly rougher surfaces than other roller types.

GENERAL OBSERVATIONS

Several items noted with previous use of vibratory rollers on HMAC surfaces were of principal concern to this study. One is small ripples in the pavement that are often induced by vibrating action of the drum or drums. This rippling effect which occurs in the longitudinal direction normally is associated with higher amplitudes and lower frequency ranges of operation (2).

Practically all the experimental test sections exhibited some degree of pavement rippling. It is pointed out however that rippling was not limited to the vibratory rolled sections but was equally noticeable on conventionally compacted sections. This suggests that rippling on this particular project may have been the result of the paving operation or imperfections in the old surface and not necessarily the compaction process. The ripples were noticable only in the direction of sunlight and could not be measured with straightedge equipment or detected from a moving vehicle.

Another concern of using vibratory rollers to compact asphaltic concrete is tracking by drive wheels, particularly when rubber tires are used. As indicated by previous discussion, tracks or tire marks could not be measured on this project. However, surface imprints or wheel marks could be viewed during and immediately following rolling operations. Imprints were somewhat more noticable with rubber tires as opposed to steel wheel driven machines. Double drum rollers leave virtually no surface imprints when rolling.

Although rubber tire rollers do mark the surface during rolling, the tracks disappear a short time after traffic is allowed to travel on the compacted mix. Consequently, the problem is considered to be minor and not detrimental to the end result pavement.

A few instances were noted on the wearing course where small longitudinal cracks developed in the center of lanes compacted with double drum rollers. Although the cracking is not extensive, it is a cause of concern. It is felt that the cracks are a result of insufficient overlap of the drums on successive passes. The double drum rollers employed on this project were equipped with drums approximately one-half the width of a single lane. Operators therefore tried to compact each section using side by side coverages rather than make an additional coverage to obtain sufficient overlap. When adequate overlap was provided for, cracking was not a problem.

Several other observations in regards to roller performance are noteworthy. All except one of the small vibratory rollers had little or no difficulty maintaining the pace of the paving operation on this particular project. A full day's production normally accounted for about 1500 tons (1.36 E6 Kg.) of mix. The fewer number of passes required by the vibratory rollers and their ability to compact mixes at higher temperatures enabled them to keep pace with the pavement at a rate comparable to conventional rollers. The following table gives an indication of compaction times and rates for the various rollers on the wearing course of this particular project.

Table 5

Roller(s) Name	Average Rolling Time (min.-sec.)	Average Rolling Distance	Average Rate per 100 ft. (30.5 m) of lane (min.)
Rex SP-900	8-20	230 (70.1 m)	3.62
Bros SWV-735SV	8-15	500 (152.4 m)	1.65
Raygo Rustler 404-B	11-0	400 (121.9 m)	2.75
Dynapac CC42A	9-15	300 (91.4 m)	3.08
Buffalo Bomag BW-210	6-0	270 (82.3 m)	2.22
Tampo 166A	6-45	400 (121.9m)	1.69
Conventional Rollers	13-45	288 (87.8 m)	4.77

Average rate of compaction for vibratory rollers = 2.50 min. per 100 ft.

Average rate of compaction of conventional rollers = 4.77 min. per 100 ft.

In effect these rates suggest that vibratory rollers are capable of compacting pavements in about one-half the time required by the three conventional rollers. It is pointed out, however, that these values are only applicable to this project and should not be mistaken to be representative of maximum output. The controlling factor in most cases was the speed of the paving operation and not that of the roller. As indicated above, all except one of the small rollers were easily able to keep pace with the spreader and thus their full potential could not be measured.

Care must be taken when vibratory rollers are used in compacting asphaltic concrete to insure against over-compaction. Excessive compactive effort can result in additional crushing of large aggregate particles and in turn, can reduce pavement density. One instance of this on the binder course was noted on this project. Roadway cores were examined after it was found that densities produced were below specification requirements and it was noted that some breakage of large aggregates had occurred.

Several field cores taken from sections compacted with vibratory rollers were separated to determine if aggregates were segregating between the upper and lower halves of a given layer. Some agencies have reported that fine materials tend to migrate to the top of a layer compacted with vibratory equipment. Although the sampling was insufficient upon which to base firm conclusions, results failed to indicate that any significant amount of aggregate segregation had taken place.

CONCLUSIONS

The following are conclusions reached on the first phase of Louisiana's Vibratory Roller Evaluation Study.

1. Relative pavement densities produced by vibratory rollers compared favorably with relative densities obtained from conventional rolling.
2. Surface smoothness measurements determined by the ten foot (3.0 m) rolling straightedge and the May's Roughometer indicate that pavements compacted with vibratory rollers were similar in smoothness to pavement sections rolled with conventional equipment.
3. Variability in pavement densities is slightly greater for vibratory compacted sections of pavement than for conventionally rolled sections.
4. Vibratory rollers require a fewer number of passes to achieve maximum pavement density than do conventional static weight rollers.
5. No correlation was found to exist between compacted roadway densities and aggregate gradations determined by percent passing the No. 4 and No. 40 U. S. Sieves.
6. Vibratory rollers operating in a static mode produced lower roadway densities than when operating in a vibratory mode.
7. Performance of the various vibratory rollers tested was largely dependent upon rolling methods and operator experience.
8. The general appearance of a surface compacted with a vibratory roller is equal in quality to the appearance of a surface rolled with conventional static weight rollers.

RECOMMENDATIONS

On the basis of findings obtained from this particular project which indicate that vibratory rollers are capable of compacting asphaltic concrete pavements to a relative density and surface smoothness required by end result specifications, it is recommended that Department specifications be amended to permit the use of vibratory rollers on all existing and future construction projects. As reflected under Implementation previously, the Department has already adopted this recommendation and is proceding with specification changes accordingly (Appendix).

Continued research in evaluating vibratory rollers under field conditions is essential before final conclusions can be formulated. The second project under this two part evaluation will contribute considerably to this end.

Additional research with vibratory rollers is needed to provide information concerning the following uses.

1. Density growth criterion on various thicknesses of asphaltic concrete to establish optimum rolling patterns, speeds, number of passes, static weights, frequencies of vibration and amplitudes.

2. Effects of vibratory compaction over weak subgrades and high water tables typical of Louisiana conditions.

3. Vibratory limitations in regard to aggregate fracture and asphalt migration.

REFERENCES

1. Standard Specifications for Roads and Bridges, Louisiana Department of Highways, October 1971.

2. Report on: Use of Vibratory Rollers for Compaction of Asphaltic Concrete, FHWA Notice HO-31, U. S. Department of Transportation, Federal Highway Administration, March 1972.

3. Cechetini, J. A., and Sherman, G. B., Highway Research Report: Vibratory Compaction of Asphalt Concrete Pavements, Interim Report No. 3, California Division of Highways, 1973.

4. Evaluation of the Ray-Go Vibratory Roller for the Compaction of Asphaltic Concrete, Summary Report for New Product Evaluation, Offer No. 14-D, Louisiana Department of Highways, November 1971.

5. State of the Art: Compaction of Asphalt Pavements, Special Report No. 131, Highway Research Board, 1972.

6. Wester, K., Symposium - Asphalt Paving for the 70's: Compaction, Proceedings. The Association of Asphalt Paving Technologists, Vol. 40, pp. 279-293, 1971.

APPENDIX

SPECIFICATIONS FOR TYPE 1 MIXTURE

US SIEVE SIZE	PERCENT PASSING (BY WT.)	
	Binder Course	Wearing Course
1 1/4 in. (3.2 cm)	100	____
1 in. (2.5 cm)	90-100	100
3/4 (1.9 cm)	75-100	85-100
1/2 in. (1.3 cm)	55-95	70-100
3/8 in. (1.0 cm)	____	____
No. 4	35-70	40-70
No. 10	20-50	25-55
No. 40	10-30	8-30
No. 80	5-20	4-20
No. 200	2-10	2-10
Bitumen %	3.0-6.0	3.5-7.0
Mineral Agg. %	94.0-97.0	93.0-96.5
% Mineral Filler (min.)	2	3
% Crushed Retained on No. 4	60 min.	75 min.

Marshall Stability @ 140°F (60°C)
a) Desirable 1650 lbs. (7339.2 N)
b) Min. Requirement 1200 lbs. (5337.6 N)

Flow - 15 max.

GRADATION DATA FOR BINDER COURSE MIX

OBS	DATE	TIME	LABGR	THGR	STAB	FLOW	BN1	BN2	BN3	BN4	MF	AC	CR	P3/4	P1/2	PN4	PN10	PN40	PN80	PN200	EXAC	STMP	ATMP
1	11/15/73	PM	2.340	2.46	1005	5	49.7	8.6	12.5	22.9	1.9	4.4	71	100	78	53	44	26	8	5	3.9	265	82
2	11/16/73	AM	2.340	2.46	1395	4	49.7	12.4	6.7	24.9	1.9	4.4	69	98	83	59	49	31	12	8	4.5	270	78
3	11/16/73	PM	2.350	2.46	1313	5	49.7	12.4	6.7	24.9	1.9	4.4	66	100	86	57	47	29	10	6	4.6	270	78
4	11/17/73	PM	2.345	2.46	1172	7	49.6	14.3	7.6	21.9	1.9	4.6	60	100	90	59	48	30	11	7	4.8		78
5	11/19/73	AM	2.365	2.46	1362	5	49.7	14.3	7.6	21.9	1.9	4.6	64	100	80	58	43	28	12	8	4.6	285	78
6	11/19/73	PM	2.360	2.46	1375	6	49.7	14.3	7.6	21.9	1.9	4.6	62	100	86	53	39	26	11	7	4.6	285	78
7	11/20/73	PM	2.355	2.46	1448	8	49.7	14.3	7.6	21.9	1.9	4.6	55	100	86	53	42	27	12	8	4.3	300	84
8	11/21/73	AM	2.355	2.47	1329	9	49.7	14.3	7.6	21.9	1.9	4.6	61	100	88	56	42	28	13	8	4.5	300	78
9	11/21/73	PM	2.360	2.47	1413	10	49.7	14.3	7.6	21.9	1.9	4.6	81	97	94	55	43	28	12	7	4.6	300	78
10	11/24/73	AM	2.360	2.47	1530	10	49.7	14.3	7.6	21.9	1.9	4.6	68	100	90	57	43	30	14	9	4.6	300	78
11	11/24/73	PM	2.355	2.47	1232	7	49.7	14.3	7.6	21.9	1.9	4.6	62	100	91	60	46	30	13	8	4.8	300	78
12	11/29/73	AM	2.340	2.47	1320	7	49.7	14.3	7.6	21.9	1.9	4.6	70	100	89	59	47	30	12	8	4.3	300	58
13	11/29/73	PM	2.335	2.47	1294	8	49.7	14.3	7.6	21.9	1.9	4.6	70	100	88	60	49	32	13	8	4.3	300	58
14	11/30/73	AM	2.360	2.47	1302	9	49.7	14.3	7.6	21.9	1.9	4.6	55	99	79	52	43	28	10	6	4.5	300	70
15	11/30/73	PM	2.360	2.47	1437	10	49.7	14.3	7.6	21.9	1.9	4.6	51	100	89	57	46	29	12	8	4.9	300	70
16	12/01/73	AM	2.330	2.47	1246	7	49.7	14.3	7.6	21.9	1.9	4.6	68	100	88	61	49	32	10	6	5.0	300	
17	12/01/73	PM	2.345	2.47	1463	10	49.7	14.3	7.6	21.9	1.9	4.6	69	94	73	56	46	30	10	6	4.8		
18	12/03/73	AM	2.335	2.47	1568	9	49.7	14.3	7.6	21.9	1.9	4.6	65	100	90	64	53	36	15	11	4.8	335	60
19	12/03/73	PM	2.350	2.47	1381	10	49.7	14.3	7.6	21.9	1.9	4.6	46	100	88	58	48	33	12	8	4.9	335	60
20	12/04/73	AM	2.340	2.47	1473	6	49.7	14.3	7.6	21.9	1.9	4.6	70	98	85	56	46	30	10	8	4.4		50
21	12/04/73	PM	2.340	2.47	1544	7	49.7	14.3	7.6	21.9	1.9	4.6	70	97	87	59	47	30	12	8	4.7		50
22	12/05/73	AM	2.345	2.47	1590	10	49.7	14.3	7.6	21.9	1.9	4.6	69	100	90	59	46	29	13	9	4.7	330	50
23	12/05/73	PM	2.330	2.47	1501	8	49.7	14.3	7.6	21.9	1.9	4.6	69	97	87	56	45	30	10	7	4.4	300	50
24	12/06/73	AM	2.325	2.47	1450	8	49.7	14.3	7.6	21.9	1.9	4.6	69	99	86	57	44	28	9	6	4.2	330	45
25	12/06/73	PM	2.330	2.47	1410	8	49.7	14.3	7.6	21.9	1.9	4.6	64	100	87	57	48	33	12	8	4.4	330	50

ABBREVIATIONS

OBS = Observation number.
LABGR = Specific Gravity of laboratory briquette.
THGR = Theoretical specific gravity.
STAB = Marshall stability (lbs.).
BN( ) = Bin percentages of aggregate.
MF = Mineral filler percentage.
AC = Asphalt content (%).
CR = Percent of crushed aggregate retained on No. 4 sieve.
P( ) = Percent of aggregate passing designated sieve size.
EXAC = Extracted asphalt content (%).
STMP = Spreader Temperature (°F).
ATMP = Ambient or Air Temperature (°F).

GRADATION DATA FOR WEARING COURSE MIX

OBS	DATE	TIME	LABGR	THGR	STAB	FLOW	BN1	BN2	BN3	MF	AC	CR	P3/4	P1/2	PN4	PN10	PN40	PN80	PN200	EXAC	TTMP	STMP	ATMP
1	01/07/74	PM	2.330	2.44	2085	6	39.7	24.7	27.4	2.8	5.2	84	100	95	47	32	17	8	6	5.7	334	302	51
2	01/17/74	AM	2.330	2.44	1524	12	50.2	22.8	19.0	2.8	5.2	84	100	97	60	41	23	11	7	5.8	349	299	78
3	01/18/74	AM	2.320	2.44	1883	10	48.3	24.7	19.0	2.8	5.2	81	100	96	53	37	22	11	7	5.3	348	299	77
4	01/18/74	PM	2.300	2.44	1278	10	48.3	24.7	19.0	2.8	5.2	83	100	98	59	40	21	9	6	5.5	348	299	77
5	01/22/74	PM	2.335	2.44	1790	8	48.3	24.7	19.0	2.8	5.2	82	100	99	57	58	22	11	7	5.7	331	308	79
6	01/29/74	AM	2.321	2.44	1675	9	48.3	24.7	19.0	2.8	5.2	79	100	96	54	39	22	9	5	4.9	349	328	75
7	01/29/74	PM	2.315	2.44	1747	8	48.3	24.7	19.0	2.8	5.2	80	100	97	61	42	24	12	9	5.0	349	328	75
8	01/30/74	AM	2.333	2.44	1714	9	50.2	20.9	20.9	2.8	5.2	80	100	98	58	44	27	12	8	4.7	369	342	65
9	01/30/74	PM	2.346	2.44	1731	12	50.2	20.9	20.9	2.8	5.2	82	100	99	61	45	27	14	9	5.1	369	342	65
10	01/31/74	AM	2.330	2.44	1607	11	50.2	20.9	20.9	2.8	5.2	85	100	97	60	42	24	11	8	5.5	364	340	60
11	01/31/74	PM	2.325	2.44	1581	10	50.2	20.9	20.9	2.8	5.2	82	100	97	59	43	24	13	9	5.2	361	344	60
12	01/31/74	PM	2.325	2.44	1581	10	50.2	20.9	20.9	2.8	5.2	82	100	97	59	43	24	13	9	5.2	353	327	60
13	02/04/74	AM	2.315	2.44	1925	7	50.2	20.9	20.9	2.8	5.2	81	100	96	58	40	23	11	8	5.2	363	339	65
14	02/04/74	AM	2.315	2.44	1925	7	50.2	20.9	20.9	2.8	5.2	81	100	96	58	40	23	11	8	5.2	362	329	65
15	02/04/74	PM	2.315	2.44	1566	8	50.2	20.9	20.9	2.8	5.2	80	100	98	62	45	23	10	7	5.1	360	335	65
16	02/05/74	AM	2.330	2.44	1555	11	50.2	20.9	20.9	2.8	5.2	84	100	97	54	40	25	12	8	5.2	338	318	50
17	02/05/74	PM	2.330	2.44	1689	8	50.2	20.9	20.9	2.8	5.2	82	100	95	59	42	21	9	6	5.3	353	331	50
18	02/11/74	AM	2.325	2.44	1587	9	50.2	20.9	20.9	2.8	5.2	86	100	96	56	41	26	11	7	5.3	326	295	65
19	02/11/74	PM	2.325	2.44	1569	9	50.2	20.9	20.9	2.8	5.2	81	100	98	65	49	32	14	9	5.2	326	295	65
20	02/12/74	AM	2.315	2.44	1478	8	50.2	20.9	20.9	2.8	5.2	78	100	97	62	45	26	12	8	5.0	329	298	65

ABBREVIATIONS

OBS = Observation number.
LABGR = Specific Gravity of laboratory briquette.
THGR = Theoretical specific gravity.
STAB = Marshall stability (lbs.)
BN( ) = Bin percentages of aggregate.
MF = Mineral filler percentage.
AC = Asphalt content (%).
CR = Percent of crushed aggregate retained on No. 4 sieve.
P( ) = Percent of aggregate passing designated sieve size.
EXAC = Extracted asphalt content (%).
STMP = Spreader Temperature (°F).
ATMP = Ambient or Air Temperature (°F).

ROADWAY DATA ON BINDER COURSE SECTIONS

OBS	SECTN	RT	FROM STA	TO STA	LN	VPASS	NV	AVGDV	SDV	MINDV	MAXDV	TOL10H	TOL10L	TOL15H	TOL15L	R
1	01EXP	RE	1077+95	1031+00	RT	VIBRT11	8	96.1	1.06	94.0	97.0	.07	0.41	0.21	1.92	9
2	01EXP	RE	1077+95	1031+00	LF	VIBRT11	8	96.2	0.86	95.3	97.9	.12	0.41	1.38	4.65	7
3	02CON		976+76	933+00	RT	B3P20T3	6	97.4	1.22	95.3	98.3	.22	0.57	1.05	2.26	7
4	02CON		976+76	933+00	LT	B3P20T3	8	97.1	0.76	96.0	98.5	.18	0.30	0.60	2.54	7
5	03EXP	BR	891+50	835+00	LT	VIBRT 9	10	96.5	0.72	95.5	97.7	.12	0.83	0.89	2.32	7
6	03EXP	BR	891+50	835+00	RT	VIBRT 9	10	96.1	1.29	93.4	97.7	.01	0.25	0.15	2.29	7
7	04EXP	RA	789+50	749+50	RT	VIBRT11	8	97.9	0.93	96.8	99.4	.33	0.74	1.33	0.13	9
8	04EXP	RA	789+50	749+50	LT	VIBRT11	9	95.3	1.14	93.2	96.6	.00	0.58	0.70	4.57	9
9	05EXP	VP	747+00	707+00	LF	VIBRT11	8	93.7	1.77	90.7	96.2	.19	0.86	0.78	3.89	9
10	05EXP	VP	747+00	707+00	RT	VIBRT11	9	95.0	0.92	93.6	96.6	.10	1.23	0.28	4.79	9
11	06EXP	BU	704+00	665+32	LF	VIBRT 9	7	94.6	0.93	92.9	95.9	.00	0.57	1.16	2.69	8
12	06EXP	BU	704+00	665+32	RT	VIBRT 9	7	94.3	1.20	92.3	96.2	.23	0.64	0.82	3.86	6
13	07CON		622+50	660+00	RT		5	96.8	0.46	96.2	97.4	.00	1.29	0.07	5.24	8
14	08EXP	GA	616+00	570+35	LF	VIBRT 7	9	95.1	0.40	94.4	95.5	.65	1.59	1.09	3.89	10
15	08EXP	GA	616+00	570+35	RT	VIBRT 7	6	96.3	0.97	94.0	97.0	.30	1.08	0.57	4.36	11
16	09EXP	TA	567+	526+20	RT	VIBRT 9	8	96.8	0.83	95.3	97.6	.01	0.19	0.25	1.43	8
17	09EXP	TA	567+	526+20	LF	VIBRT 9	8	96.3	0.82	95.3	97.4	.13	0.67	0.18	1.06	6
18	10CON		516+79	504+50	RT		3	96.6	0.75	95.7	97.0	.22	0.60	0.51	1.57	8
19	10CON		516+79	504+50	LF		3	98.0	1.05	97.0	99.1	.15	0.63	0.85	1.46	8

ABBREVIATIONS

OBS = Observation number.
SECTN = Number of Control or Experimental Sections.
RT = Vibratory roller abbreviated.
LN = Right or Left Lane.
VPASS = Total number of roller passes.
NV = No. of core samples taken.
AVGDV = Average density (% lab. briq.)
SDV = Standard deviation of sample.
MINDV = Minimum density (% lab. briq.) of sample.
MAXDV = Maximum density (% lab. briq.) of sample.
TOL ( ) = Percent of roadway out of tolerance.
using designated rolling straightedge.
for high and low readings.
RI = May's roughness indication (in. per mi.)
ROLTM = Rolling time per 100 linear ft. of roadway.
SPSS = No. of core samples from static rolled vib. sections.
AVGDS = Average density (% lab. briq.) for static rolled vib. sections.

ROADWAY DATA ON WEARING COURSE SECTIONS

OBS	SECTN	RT	FROM STA	TO STA	LN	VPASS	NV	AVGDV	SDV	MINDV	MAXDV	TOL10H	TOL10L	TOL15H	TOL15L	RI	ROLTM	SPSS	AVGDS
1	01EXP	RE	1077+95	1034+00	RT	6	8	93.9	1.95	90.1	96.1	.23	1.09	.36	2.61	106	3.62	3	94.1
2	01EXP	RE	1077+95	1034+00	LT	6	8	95.6	0.58	94.8	96.1	.01	0.28	.33	2.44	76	3.62	3	94.3
3	02CON		976+76	933+00	RT	B3P09T5	8	97.3	1.02	96.1	99.1	.05	0.08	.13	0.42	54	4.77		
4	02CON		976+76	933+00	LT	B3P09T5	8	96.0	0.97	94.4	97.4	.05	0.36	.20	2.04	63	4.77		
5	03CON		891+50	832+00	RT	B3P09T5	8	95.6	0.65	94.4	96.6	.01	0.09	.03	0.33		4.77		
6	03EXP	BR	891+50	835+00	LT	5	8	96.0	1.06	94.4	97.9	.00	0.06	.00	0.05	55	1.65	3	94.9
7	04EXP	RA	789+50	749+50	RT	5	8	96.1	0.92	95.3	97.9	.00	0.29	.00	2.82	66	2.75	3	95.6
8	04EXP	RA	789+50	749+50	LT	5	8	96.5	0.85	94.8	97.4	.00	0.50	.00	3.13	69	2.75	3	95.4
9	05EXP	VI	746+00	707+00	RT	6	6	95.6	0.80	94.4	96.6	.15	0.76	.27	3.47	71	2.75	3	95.6
10	05EXP	VI	746+00	707+00	LT	6	6	95.7	1.31	93.9	97.4	.27	1.87	.44	5.96	92	3.08		
11	06EXP	BU	704+00	665+32	RT	7	8	96.6	0.68	95.7	97.4	.00	0.02	.04	0.99	58	2.22	3	95.1
12	06EXP	BU	704+00	665+32	LT	7	8	97.3	0.86	96.1	98.7	.32	0.30	.11	2.44	67	2.22	3	96.1
13	07CON		660+00	622+50	RT	B3P09T5	8	96.0	0.75	95.3	97.4	.05	0.06	.21	1.04	68	4.77		
14	07CON		660+00	622+50	LT	B3P09T5	8	95.7	1.44	92.3	97.0	.42	0.61	.18	3.29	81	4.77		
15	08EXP	TA	567+00	526+00	RT	7	8	96.0	0.58	94.6	96.6	.07	0.34	.13	2.53	60	1.69	3	93.8
16	08EXP	TA	567+00	526+00	LT	7	6	94.9	0.44	94.3	95.6	.00	0.07	.00	1.00	63	1.69	3	95.4

ABBREVIATIONS

OBS = Observation number.
SECTN = Number of Control or Experimental Sections.
RT = Vibratory roller abbreviated.
LN = Right or Left Lane.
VPASS = Total number of roller passes.
NV = No of core samples taken.
AVGDV = Average density (% lab. briq.)
SDV = Standard deviation of sample.
NINDV = Minimum density (% lab. briq.) of sample.
MAXDV = Maximum density (% lab briq.) of sample.
TOL ( ) = Percent of roadway out of tolerance. using designated rolling straightedge. for high and low readings.
RI = May's roughness indication (in. per mi.).
ROLTM = Rolling time per 100 linear ft. of roadway.
SPSS = No. of core samples from static rolled vib. sections.
AVGDS = Average density (% lab. briq.) for static rolled vib. sections.

RECOMMENDED SUPPLEMENTAL SPECIFICATIONS
ASPHALTIC CONCRETE PAVEMENT

SUBSECTION 501.10, ROLLERS: Rollers shall be of the steel wheel and/or pneumatic tire type and shall be in good condition, capable of reversing without backlash, and shall be operated at speeds slow enough to avoid displacement of the bituminous mixture. The number and weight of the rollers shall be sufficient to compact the mixture to the required density and surface smoothness while it is still in a workable condition and shall be capable of maintaining the pace of the bituminous paver or paving operation. The use of equipment which results in excessive crushing of the aggregate will not be permitted. Vibratory rollers with separate controls for energy and propulsion and especially designed for asphaltic concrete compaction may be used in accordance with the limits stated in this Subsection.

Vibratory rollers may be used for compaction of asphaltic concrete overlays of existing pavement. These rollers will not be allowed for compaction of new pavements unless all phases of construction have been compacted by vibratory means. Vibratory rollers are not to be used at locations with high water tables when it is determined by the engineer that such usage may cause a decrease in stability of the pavement structure.

All rollers shall have suitable equipment for keeping rollers or tires clean and efficiently dispensing water to the contact surfaces to prevent mixture pickup.

In shoulder construction one or more of the rollers specified or other approved rollers may be used provided all other specification requirements are met.

The Department reserves the right to reject poorly performing rollers and requires that they be replaced with suitable equipment or supplemented as may be necessary to accomplish the desired results.