VIBRATORY ROLLER EVALUATION STUDY

FINAL REPORT

by

LACEY A. GLASCOCK
BITUMINOUS RESEARCH ENGINEER

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The author wishes to express appreciation to the various vibratory roller manufacturers for their willingness to cooperate in conducting this research study. The author also gratefully acknowledges the cooperation extended by T. L. James Construction Company and Louisiana Paving Company, Inc., contractors on the two construction projects involved in this research effort.

ABSTRACT

The Louisiana Department of Highways has recently completed a program to evaluate the use of vibratory rollers in the compaction of asphaltic concrete pavements. In all, a total of nine (9) different vibratory rollers was tested along with conventional static weight rollers previously required by Specifications. 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.

Results obtained from two construction projects indicate that vibratory rollers used alone are capable of replacing the three static weight rollers in the compaction process. Overall density and surface smoothness measurements 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 study findings determined by this research 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 is needed to meet end-result specification requirements (see Appendix). Rather than specify method and type of rolling, it was the Department's 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 parentheses refer to list of references on page 37.

INTRODUCTION

Construction of hot mix asphaltic concrete (HMAC) pavements was introducted 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 a smooth riding surface which 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 the 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 tandem, 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 costly. Costs have risen considerably during recent years due to sizeable increases in prices for fuel and labor. Any reduction in those costs would result in a savings to the contractor and, in turn, to 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 their static weight. This enables the machines to impart more compative effort per pass when compared to static weight rollers. By allowing for fewer passes, production can be increased. This permits the use of one roller for the entire compaction process.

Although vibratory compaction of asphaltic concrete is still a developing operation, 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 Raygo Rustler 404 vibratory roller on a typical construction project in 1971 (4). Although this particulr 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 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 of an end result type for HMAC pavements (1). Included are specified limits for relative roadway densities as well as for 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 surface smoothness for acceptance purposes. These 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 results that repeatedly equal or exceed specified density and surface smoothness values. Consequently, any evaluation program to determine the adequacy of compaction equipment must be designed not only to answer questions related to individual roller performance but to compare the 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 nine (9) different vibratory rollers in addition to conventional static weight equipment to compact asphaltic concrete pavements on two separate construction projects. 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 initiated. 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 specification requirements to compensate for any problems that could be attributed to rolling.

The first of these two projects was completed in the fall of 1974 and consisted of an asphaltic concrete overlay on an existing two-lane surface treatment roadway, State Route La. 19 near Baton Rouge. 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 was new construction involving the placement of binder and wearing courses on top of a cement stabilized base. Thickness and type of HMAC mixture were the same as those indicated for the first project. The length of highway evaluated was approximately eight miles consisting of two lanes, 24 feet in width.

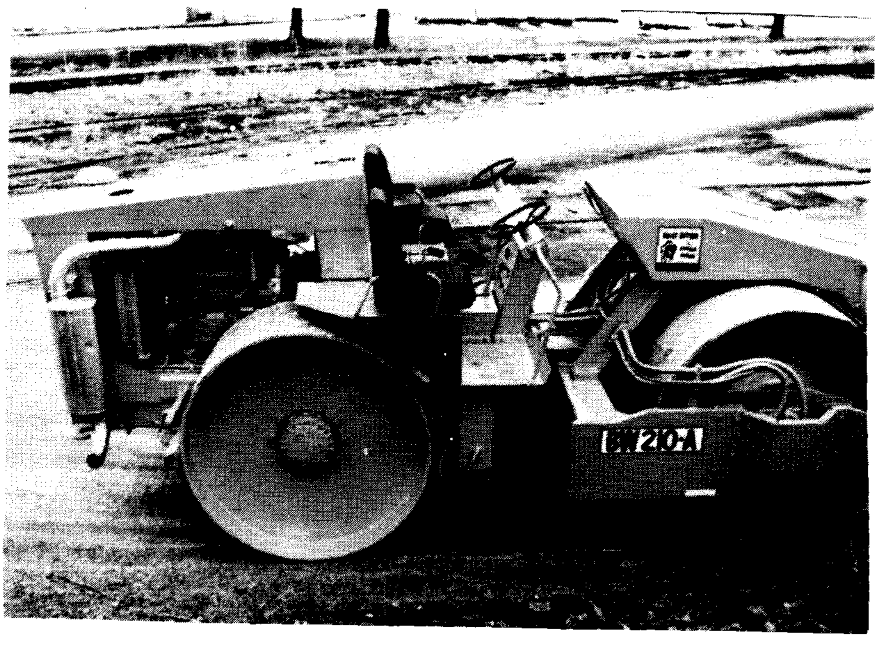
Invitations to participate in the experimental evaluations were extended to all manufacturers of vibratory rollers who market their machines in Louisiana. In all, eight accepted the invitation on the first project and six accepted the second project. Each roller was included in the evaluation program along with the contractors' three conventional rollers as indicated previously. Since this was primarily a performance evaluation, each manufacturer was asked to furnish the type of roller 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 most familiar with the operation and capabilities of his machine. Factors such as roller weight and speed, vibration frequency and amplitude, and number of passes were predetermined by each manufacturer; and, although recorded, they were not introduced as study variables.

A wide variety of rollers was selected by the various manufacturers for use on the projects. 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 appliable to each given roller.

In order to facilitate adequate collection of data, the experimental projects were 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 predetermined means. The Department maintained the use of a nuclear density device throughout construction 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 prescribed 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 proceeding 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-foot (0.9 m), 10-foot (3.0 m), 12-foot (3.7 m), and 15-foot (4.6 m) traveling straightedges.

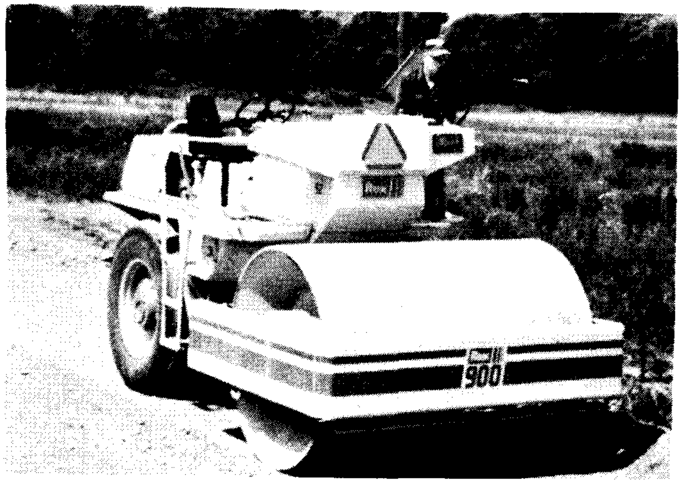
BROS SWV-735SV



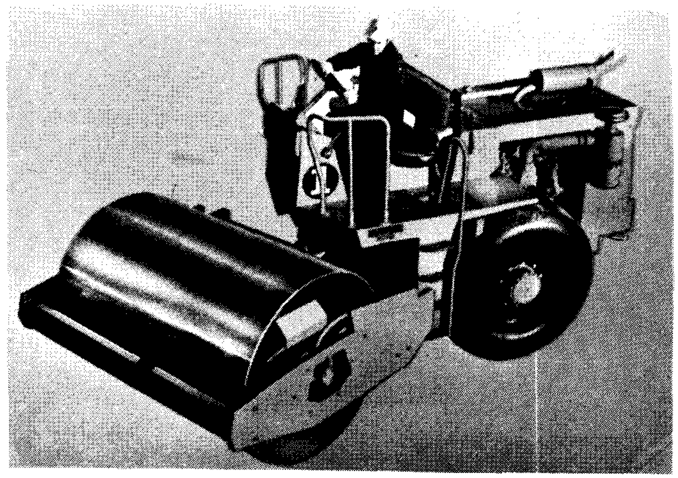
BUFFALO BOMAG BW-210A

STEEL WHEEL VIBRATORY ROLLERS

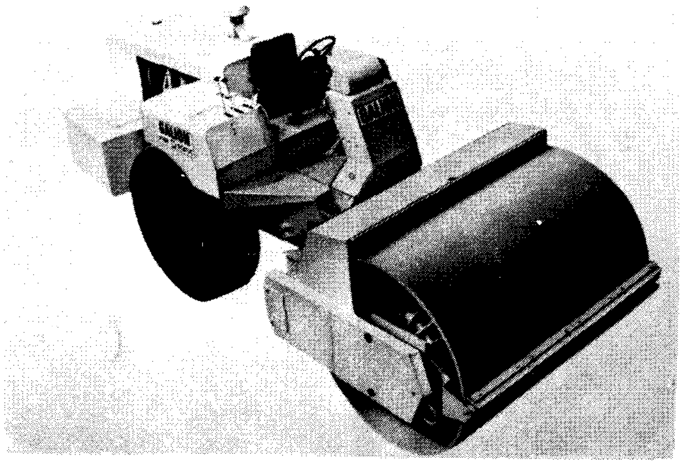
FIGURE 1



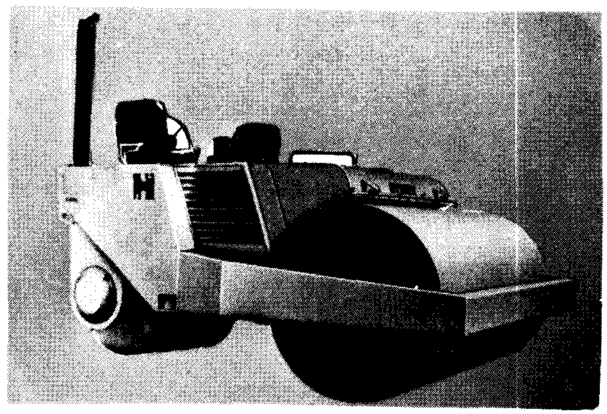
REX SP-900



RAYGO RUSTLER 404-B



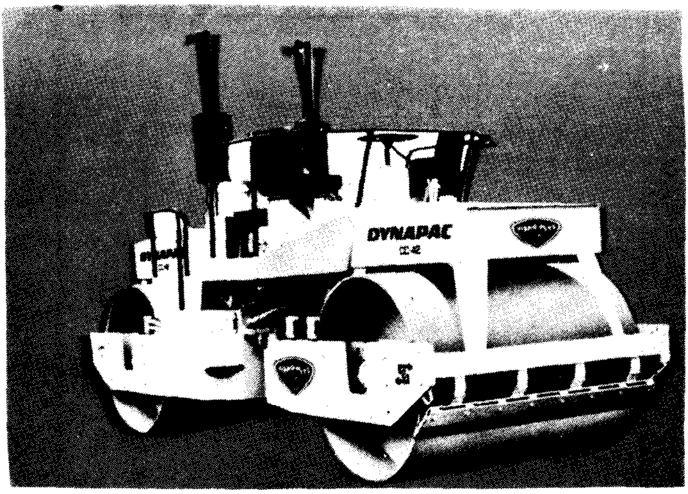
GALION VOS-84



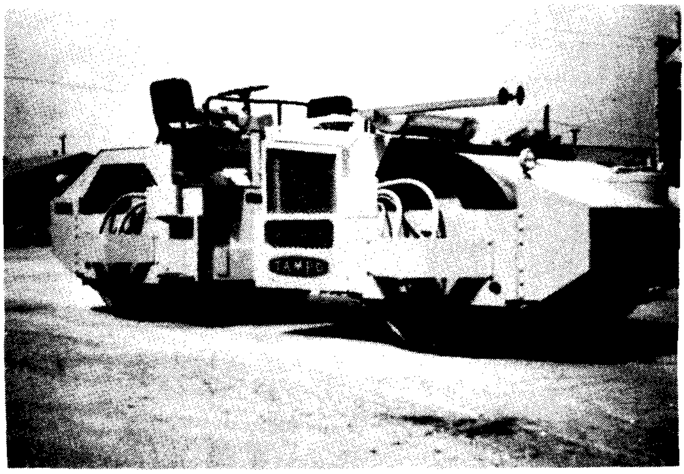
HYSTER C-625-A

RUBBER TIRE VIBRATORY ROLLERS

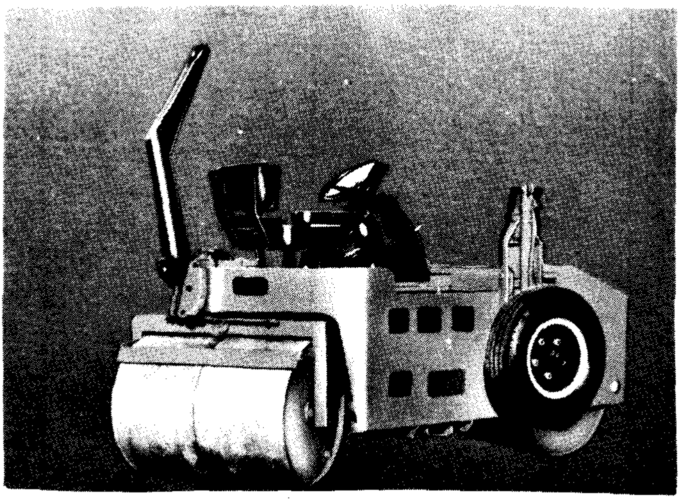
FIGURE 2



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	RAYGO RUSTLER 404 - B	DYNAPAC CC-42A	BUFFALO BOMAG BW - 210A	GALION VOS - 84	TAMPO 166A	ESSICK VR42RE	HYSTER C625A
Roller Type	Rubber Tire	Steel Wheel	Rubber Tire	Double Drum	Steel Wheel	Rubber Tire	Double Drum	Double Drum	Rubber Tire
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.	Hyster Co. 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	12-6
Width (ft.-in.)	7-11.5	8-5	7-11.5	6-6.5	7-7	7-10	6-10.5	4-3	7-8
Height (ft.-in.)	8-7	7-8	8.5	10-4	7-2	7-10.5	6-5	5-9	9-0
Weight (lbs.)	17,900	21,500	18,300	23,000	18,500	20,900	19,200	4525	15,800
Drum Diameter (in.)	60	60	59	48	59	60	48	30	48.5
Drum Length (in.)	84	84	84	66	84	84	66	42	92
Turning Radius (ft.-in.)	22-0	17-0	20-5	14-0	16-10	16-10	19-1	12-0	1-0
Wheel Base (ft.-in)	9-4	9-7	9-0	11-4	9-0	9-0	10-4	6-4.3	8-0
Curb Clearance (in.)	—	—	15-5	14.5	15.5	18	—	—	17.5
Power Plant									
Engine	GMC 3-53	GMC 3-53	DD 3-53	Cat D3145	GMC 4-53	1CH Diesel	GMC 3-53	Wis. WH4D	DD3-53
Electrical (Volts.)	12	12	12	12	12	12	12	12	12
Fuel Capacity	55	30	50	60	44	60	35	18	30
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	0-9
Tires	16.9 x 30	26 x 56 (steel)	16.9 x 30	—	26 x 56 (steel)	14 x 24	—	—	44x41
Vibration System									
Dynamic Force (lbs.)	33,500	35,000	27,000	44,000	42,000	36,000	32,000	10,000	25,000
Frequency (vpm)	0-2000	900-1700	1200-2300	2400	1100-2500	1100-1800	0-2500	3450	110-1800
Water System (gal.)	190	170	—	—	—	175	—	80	—
Front	—	—	168	115	150	—	165	—	120
Rear	—	—	15	115	40	—	165	—	10

Plant production reports were continuously monitored and recorded for any fluctuations in material 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, it was decided to evaluate the various test sections with a Mays Ride meter.* 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 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.

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* The Mays Ride Meter is an instrument for detecting pavement roughness.

DISCUSSION OF RESULTS

In evaluating the effectiveness of vibratory rollers in compacting 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, it is 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 is also shown. Although density growth relationships will not be discussed in detail in this report, 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 5 to 13. Static rolling normally

TABLE 2 - SUMMARY OF DATA BINDER COURSE

CONSTRUCTION PROJECT NO. 1

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 (3.4)
Control 1 (3-Conv. Rollers)	3-Wheel-3 Rubber Tire-20 Tandem-3	97.3	.94	.64	77.1 (3.6)
Bros SWV-735 SV (Steel Wheel)	9V	96.3	1.03	.61	71.3 (3.7)
Ray Go Rustler 404-B (Rubber Tire)	11V	96.5	1.65	.83	91.6 (3.3)
Dynapac CC42A (Double Drum)	9 to 13V	94.4	1.50	1.19	95.0 (3.2)
Buffalo Bomag BW-210A (Steel Wheel)	9V	94.5	1.05	.72	75.0 (3.6)
Control 2 (3-Conv. Rollers)	3-Wheel-3 Rubber Tire-20 Tandem-3	96.8	.46	1.29	85.4 (3.4)
Galion VOS-84 (Rubber Tire)	7V	95.6	.93	1.81	106.4 (3.0)
Tampo 166A (Double Drum)	9V	96.6	.83	.50	76.7 (3.6)
Control 3 (3-Conv. Rollers)	3-Wheel-3 Rubber Tire-20 Tandem-3	97.3	1.13	.80	85.8 (3.4)

CONSTRUCTION PROJECT NO. 2

Roller Name and Class	Number of Passes	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.*)
Control (1) (3-Conventional Rollers)	3-Wheel-5 Rubber Tire-15 Tandem-3	95.5	1.94	3.97	68.2 (3.8)
Ray Go Rustler 404-B (Rubber Tire)	4V 1S	96.0	1.05	0.29	43.1 (4.3)
Galion VOS-84 (Rubber Tire)	8V 1S	93.9	1.69	0.08	39.4 (4.4)
Dynapac CC42A (Double Drum)	8V 1S	95.6	1.45	2.26	54.4 (4.0)
Buffalo Bomay BW-210A (Steel Wheel)	8V 1S	95.8	1.53	1.11	61.5 (3.9)
Control (2) (3-Conventional Rollers)	3-Wheel-5 Rubber Tire-15 Tandem-3	96.7	1.48	0.88	----
Bros SWV-735 SV (Steel Wheel)	4V 1S	97.2	1.06	0.09	59.7 (3.9)
Hyster C-625A (Rubber Tire)	4V 1S	96.4	1.30	0.20	71.9 (3.7)

V = Vibratory Compaction

S = Static Compaction

* Numbers in parentheses represent corresponding present serviceability indices (PSI).

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 not only evident for the different types of rollers but can also be noted for many of the individual rollers between binder and wearing courses. Most of the rollers evaluated on both construction projects were able to produce higher roadway densities on the thicker lift binder course. It is significant to note, however, that three of the four failures by individual rollers to meet the 95 percent compaction requirement occurred on the binder course. Part of this could have been caused by problems in gradation control as indicated on Project No. 1 or by lack of subbase support on Project No. 2.

In order to find out if material gradation had a significant effect upon compaction, an attempt was made to determine if a correlation exists between roadway density and percentage of material passing the Number 4 and Number 40 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 favorably with those produced with conventional equipment. Slightly more consistency in results is represented 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 was analyzed for statistical properties. Standard

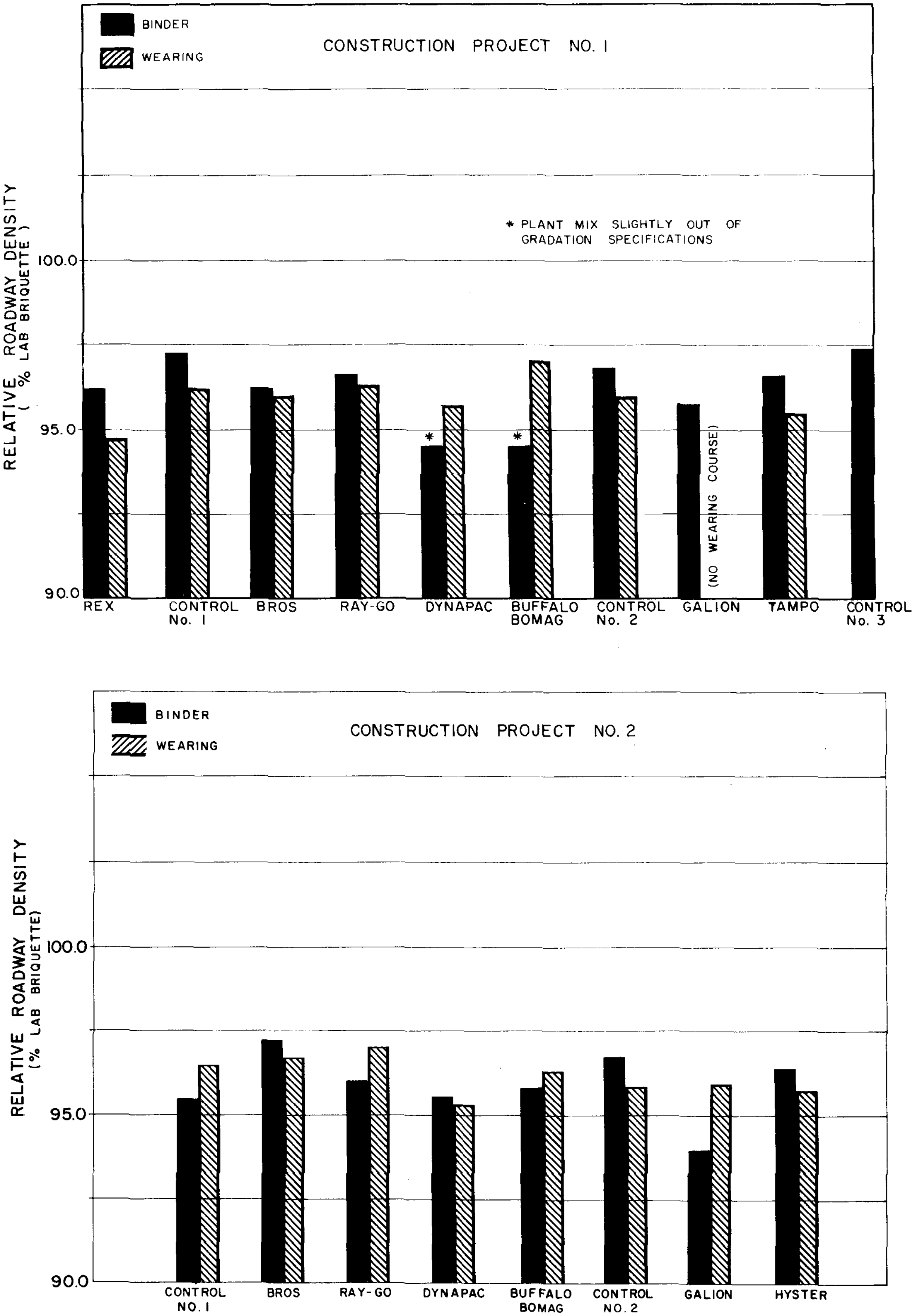


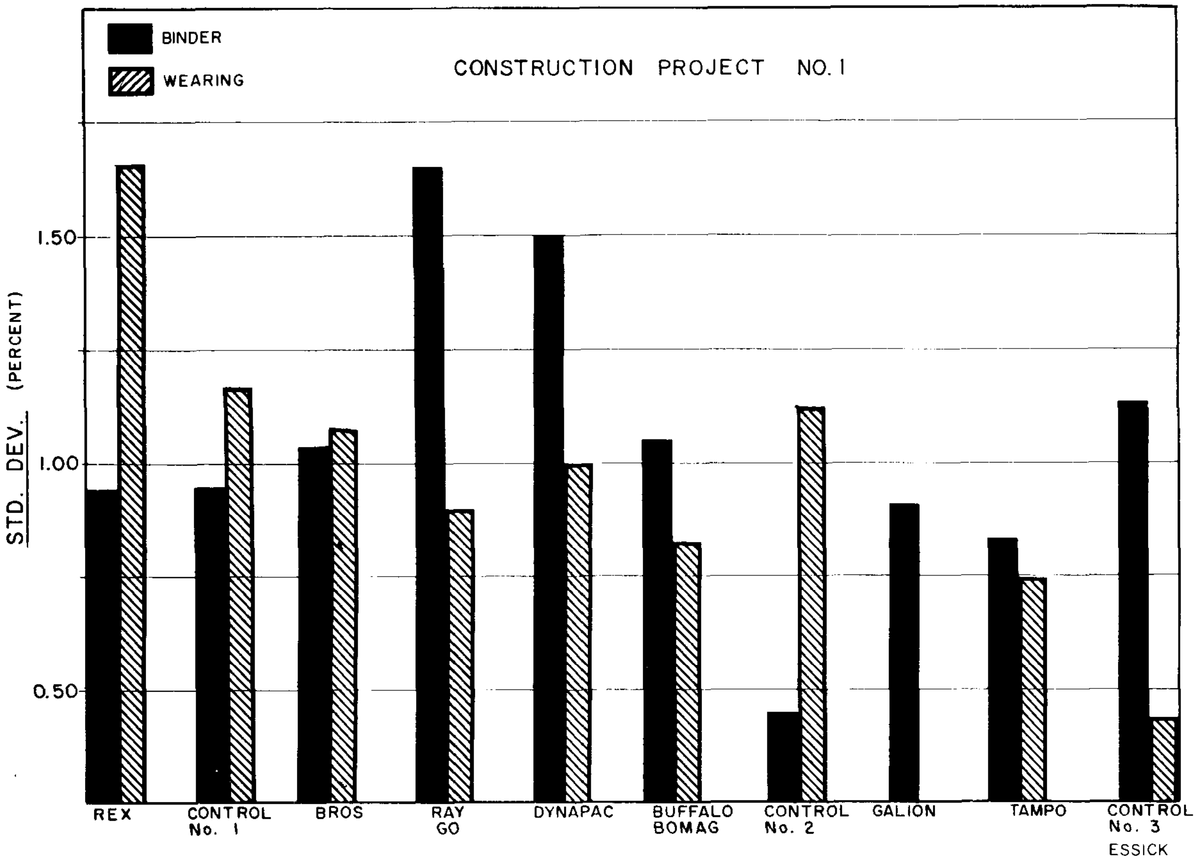
Figure 4 - Relative Densities for Individual Test Sections

deviations which are a measure of variability are listed in Tables 2 and 3 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 predominant 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 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 these projects 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 of Construction Project No. 1. 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. Three of the six rollers used on this test failed to meet the 95 percent relative compaction requirement.

Since the main interest of this study was not to compare individual rollers but to gain insight to the effectiveness of vibratory compaction, it was decided to group the data into four roller types for analysis.



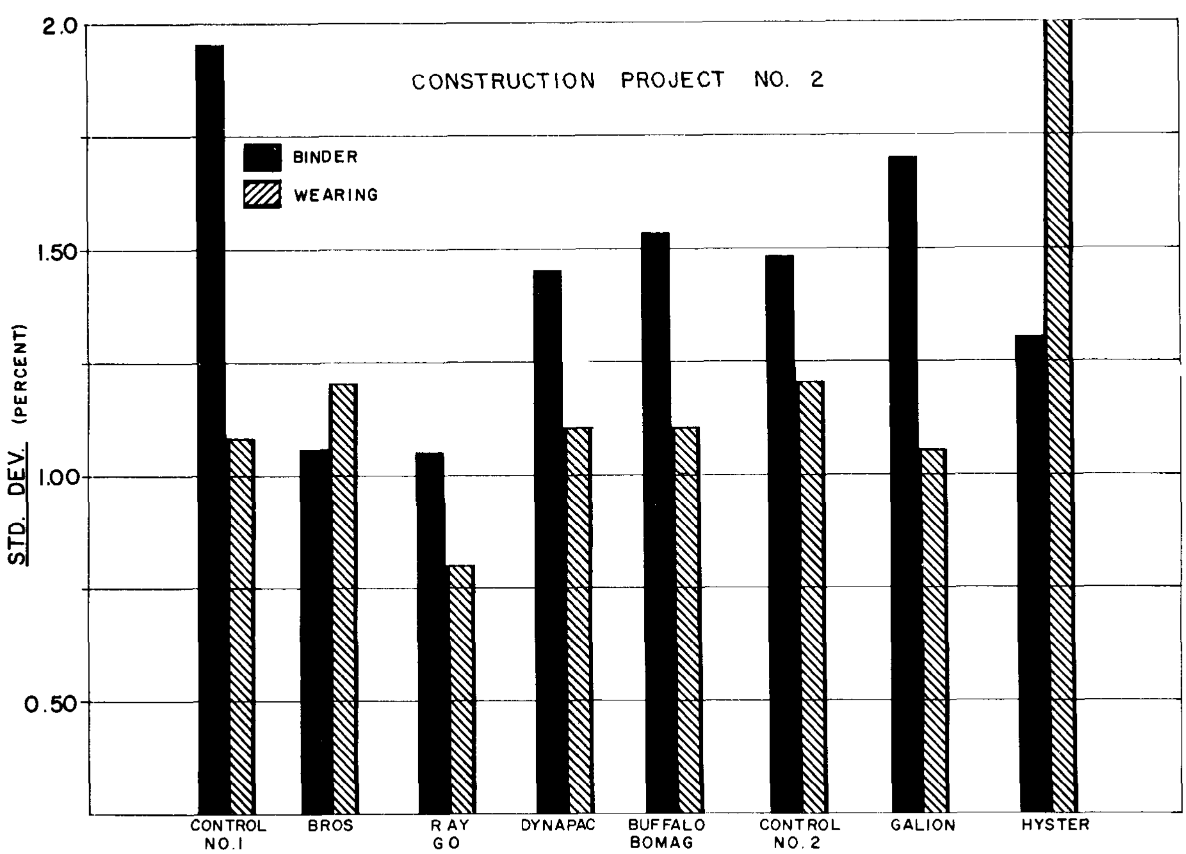


Figure 5 - Standard Deviations of Relative Densities for Individual Test Sections

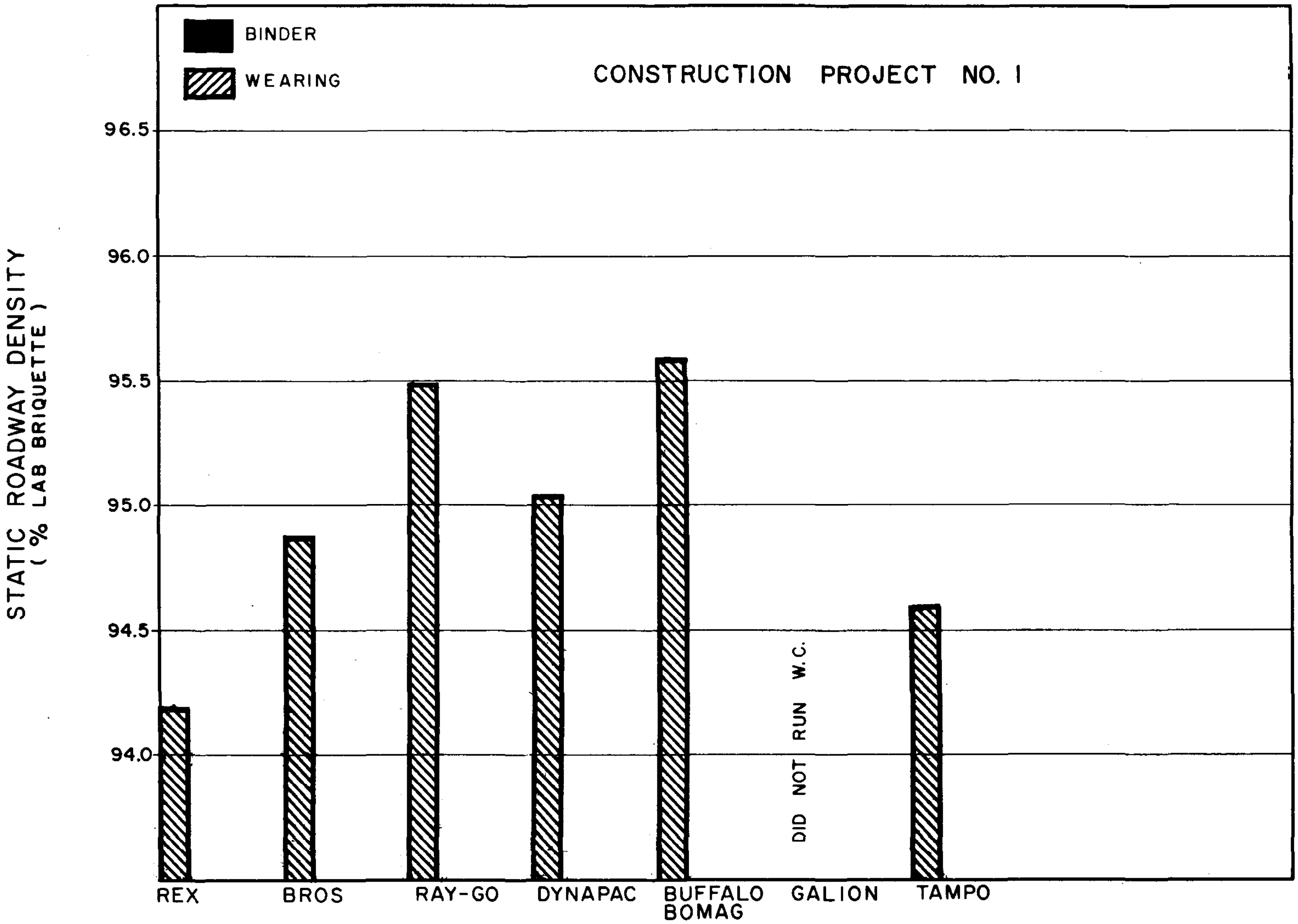


Figure 6 - Static Density Measurements for Vibratory Rollers

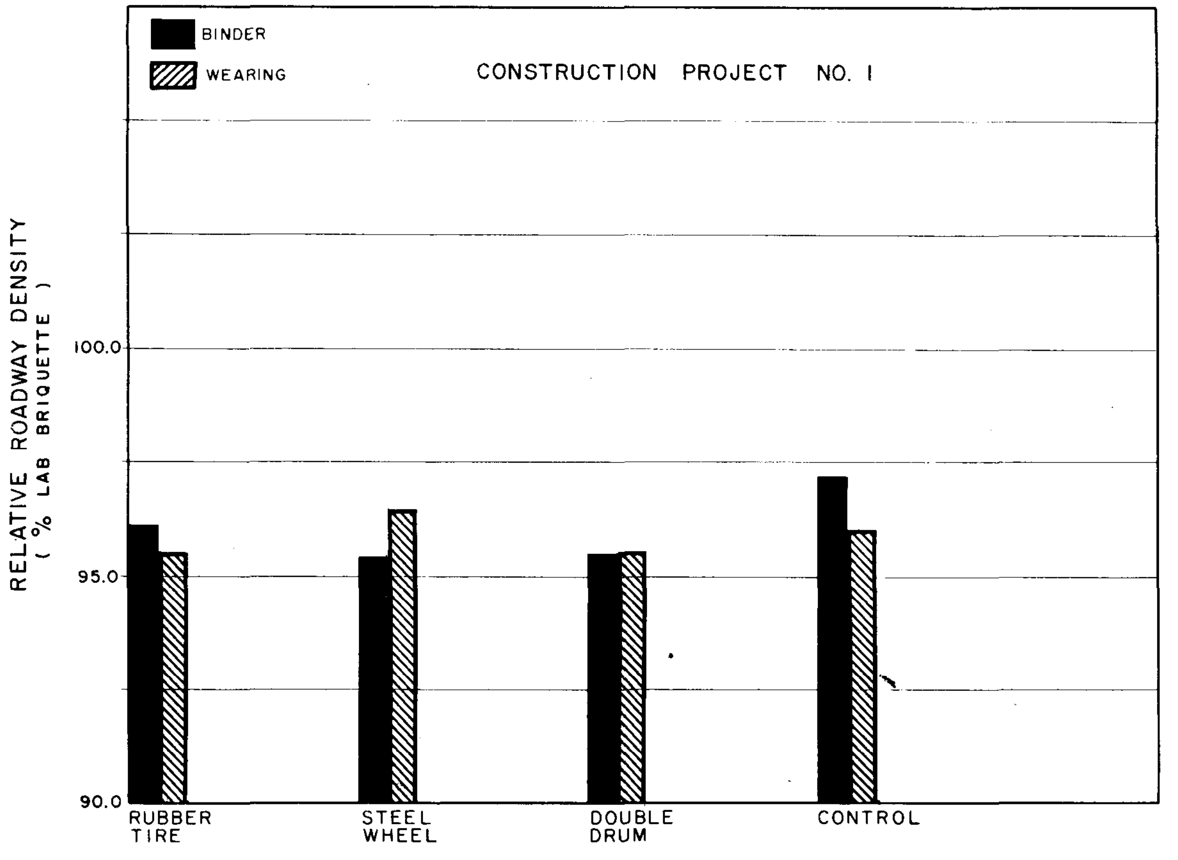
These rollers groups were (1) rubber tire vibratory rollers, (2) steel wheel vibratory rollers (3) double drum vibratory rollers and (4) the three conventional static weight rollers. Figure 7 shows graphically the results obtained from these groupings of relative densities.

Inspection of Figure 7 reveals that all four general classifications of rollers were able to meet or exceed the 95 percent relative compaction requirement. The various methods compared favorably even though control of conventional rolling resulted in slightly higher average densities than did vibratory rolling. In addition, it could not be surmised from these comparisons 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 measurement for acceptance is the 10-foot (3.0 m) rolling straightedge which has the capability of indicating sections of pavement that exceed a given tolerance over a 10-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 these projects, allowable tolerances of 1/4 inch (6.3 m) are required for the binder and wearing course respectively. Due to insufficient 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.



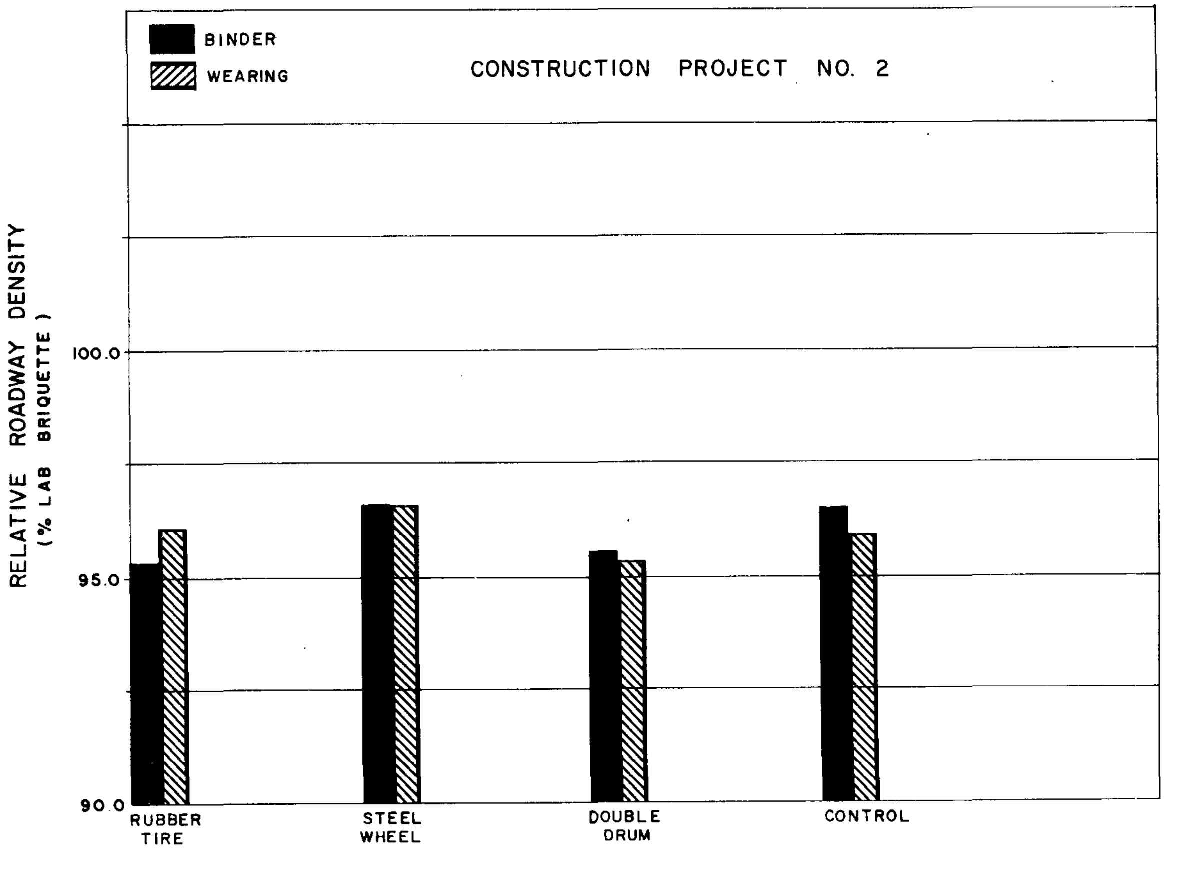


Figure 7 - Relative Densities for Roller Groups

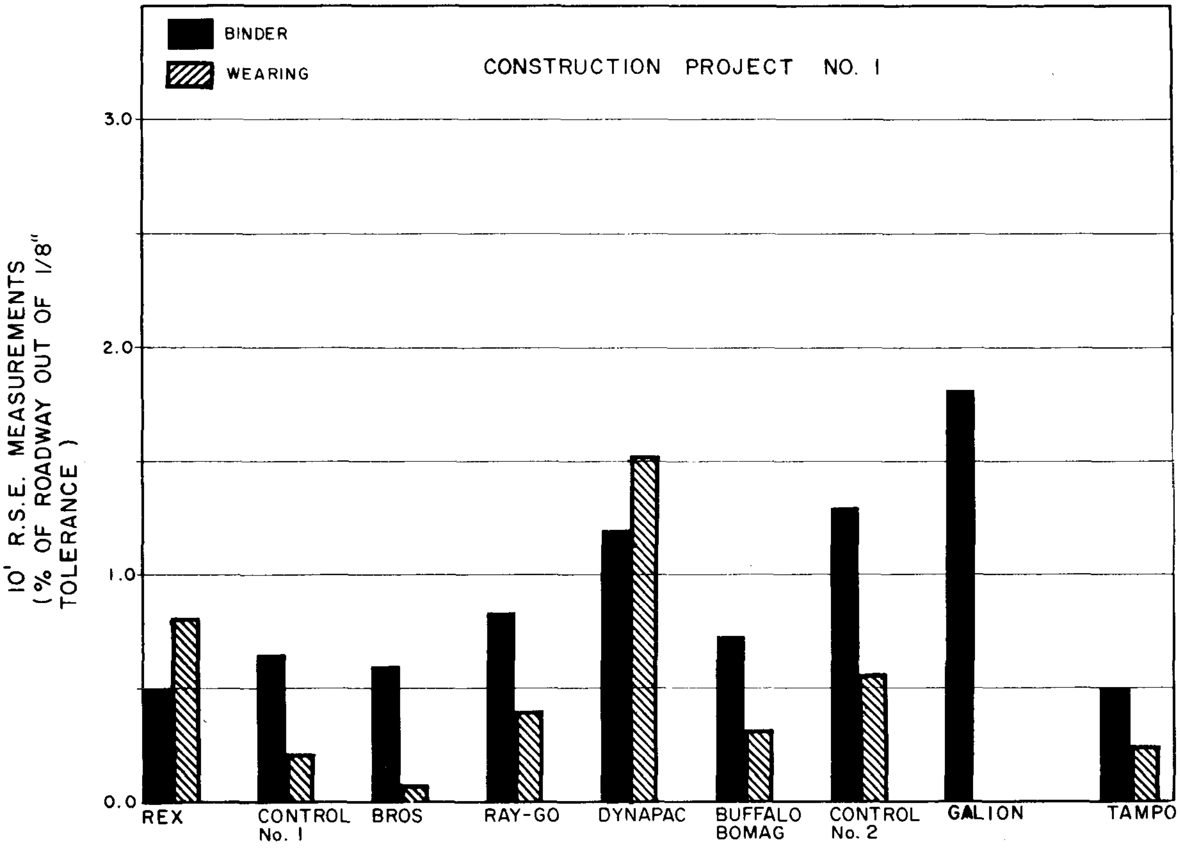
The percentage of linear roadway exceeding the specified tolerance for each of the experimental sections is shown in Figure 8. This allows visual comparison of the relative smoothness produced by each of the rolling methods as well as improvements or adverse effects obtained between the two lifts. It should be kept in mind that requirements for 100 percent payment are based on a maximum of 1-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. This one failure cannot be explained from measurements and observations in that 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 10-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 10-foot measurements are analyzed for discussion of smoothness, other straightedge readings appear to produce similar results.

An attempt was made during the early stages of Project No. 1 to measure transverse tolerances using the 3-foot (0.9 m) straightedge. The purpose of this was to quantify any pavement rutting that might be induced by the various rollers. Measurements taken were negilgible, and the process was discontinued during application of the binder course. Attempts to measure transverse depressions in the pavement with a 10-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 Mays Ridemeter. This device is designed to attach to a standard passenger vehicle and give an indication of pavement roughness at a given speed. Readings are obtained in inches or roughness per



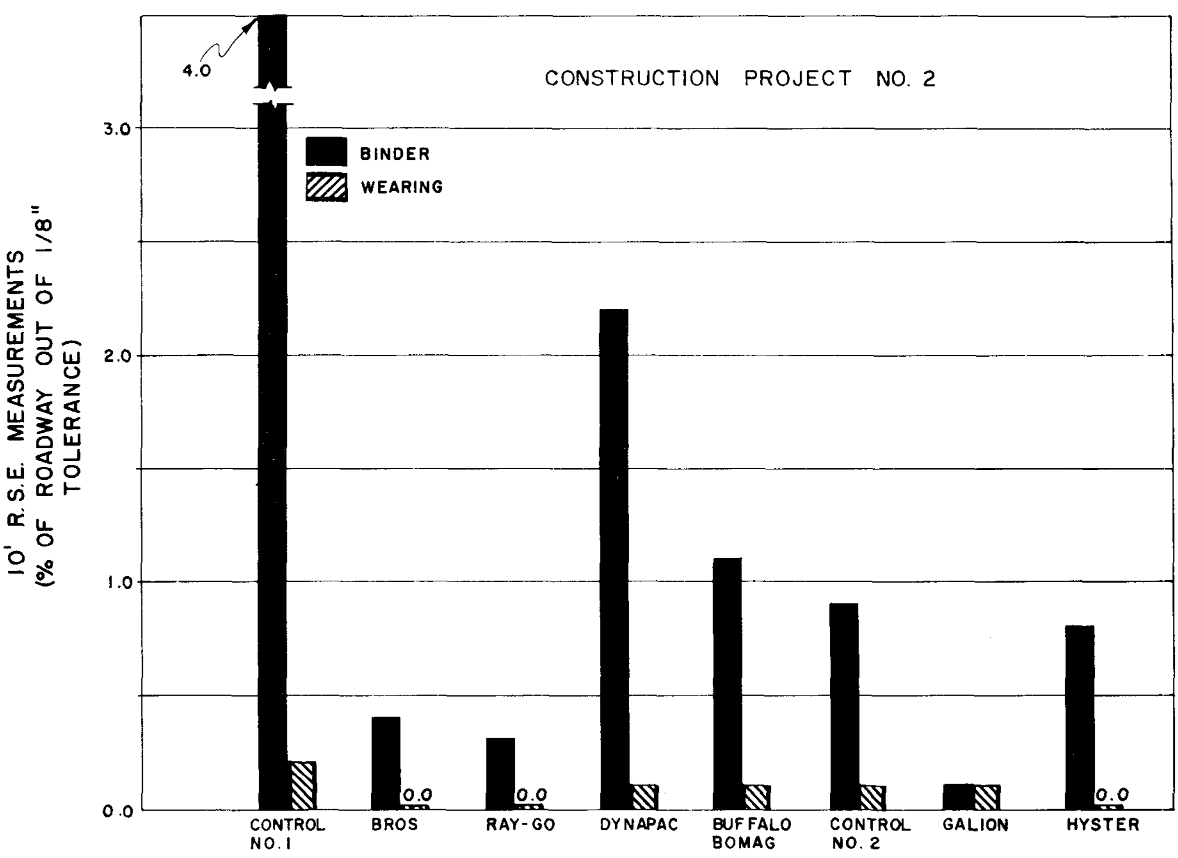


Figure 8 - Surface Tolerance Measurements for Individual Test Sections.

mile of roadway and for purposes of this discussion are converted to present serviceability index (PSI) for each experimental section (Tables 2 and 3). Higher values characterize smooth pavements while, conversely, lower values reflect rough pavements.

Bar charts showing Mays roughness measurements for each individual roller and each roller group are given in Figures 9 and 10 respectively. The data for individual rollers encompasses 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 rollers while in one instance, on each construction project, the wearing course was found to possess a greater roughness than the binder course.

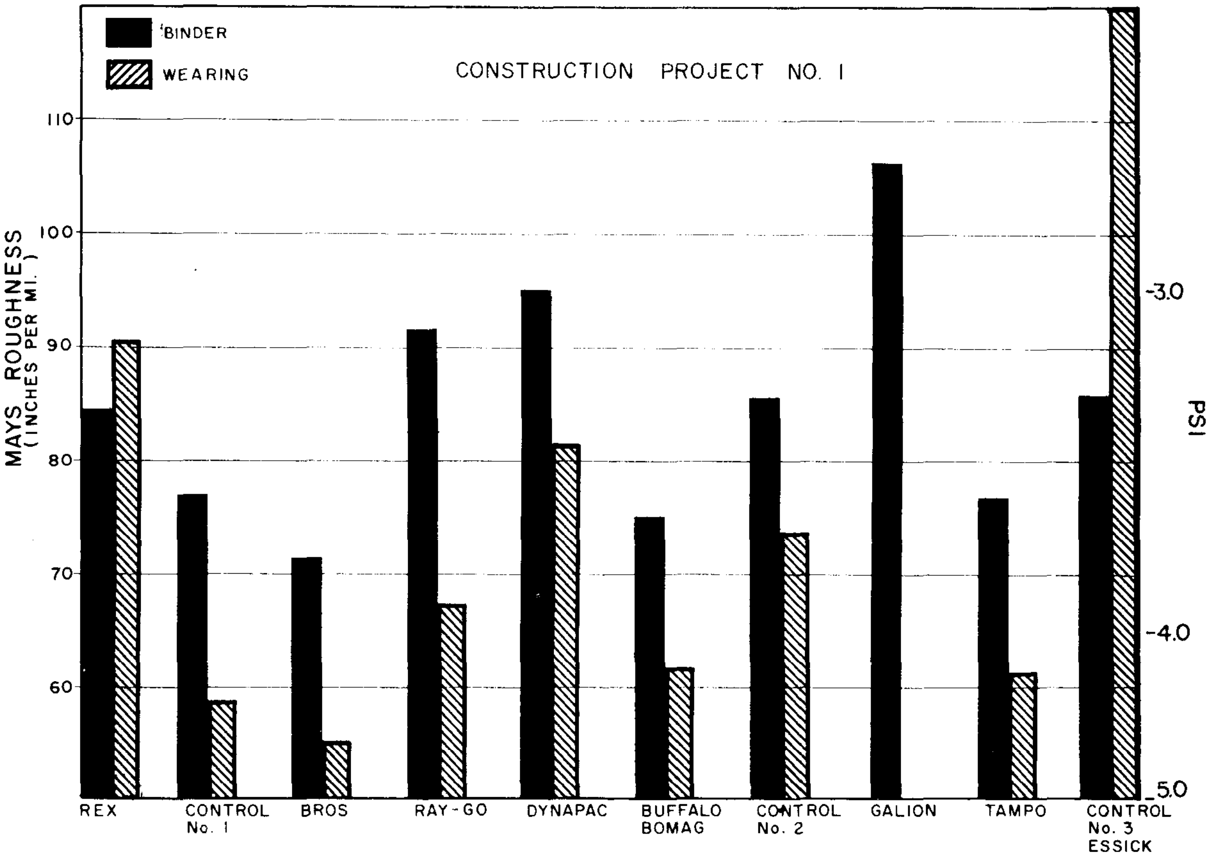
The Department uses the following Mays PSI classification as a guide in rating asphalt concrete pavements for ride quality.

Table 4

PSI	Rating
4.1 - 5.0	Very Good
3.1 - 4.0	Good
2.1 - 3.0	Fair
1.1 - 2.0	Poor
0.0 - 1.0	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.

Comparison of pavement smoothness measurements obtained with vibratory



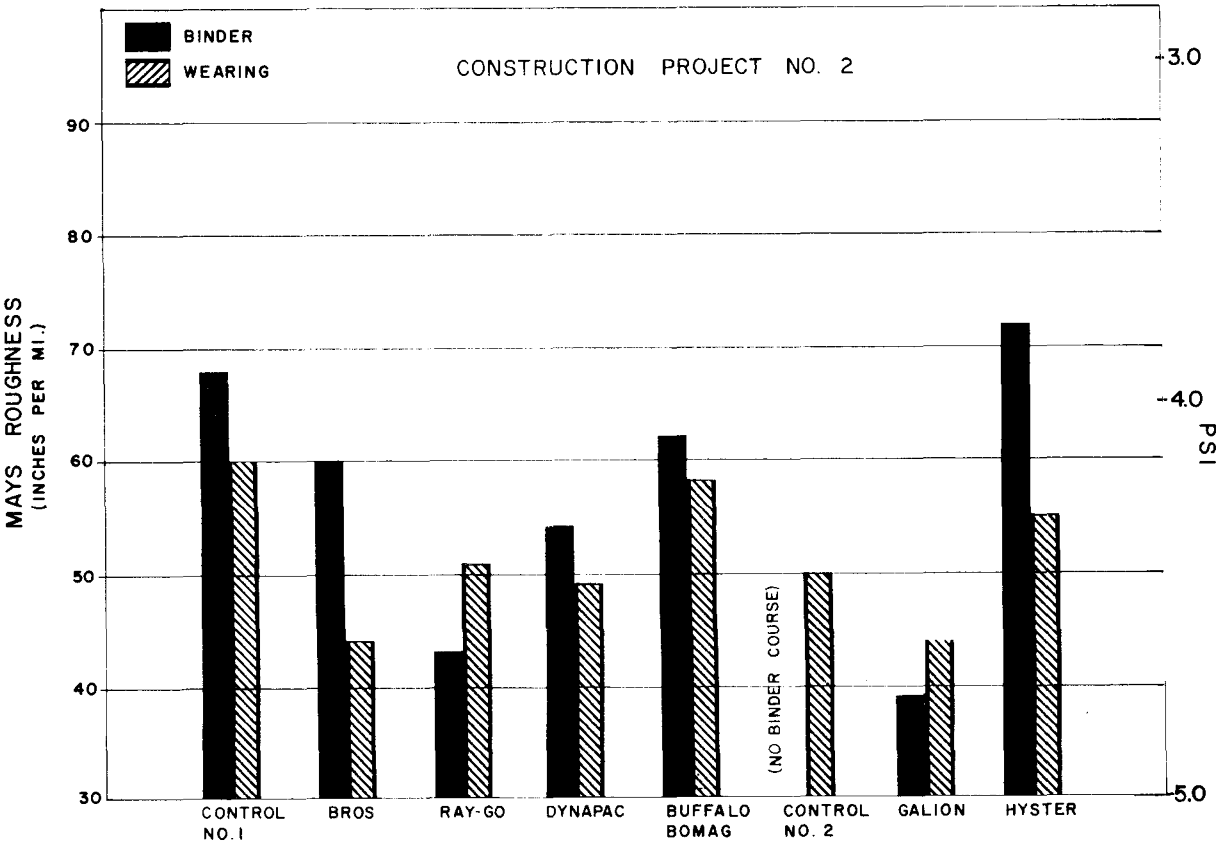
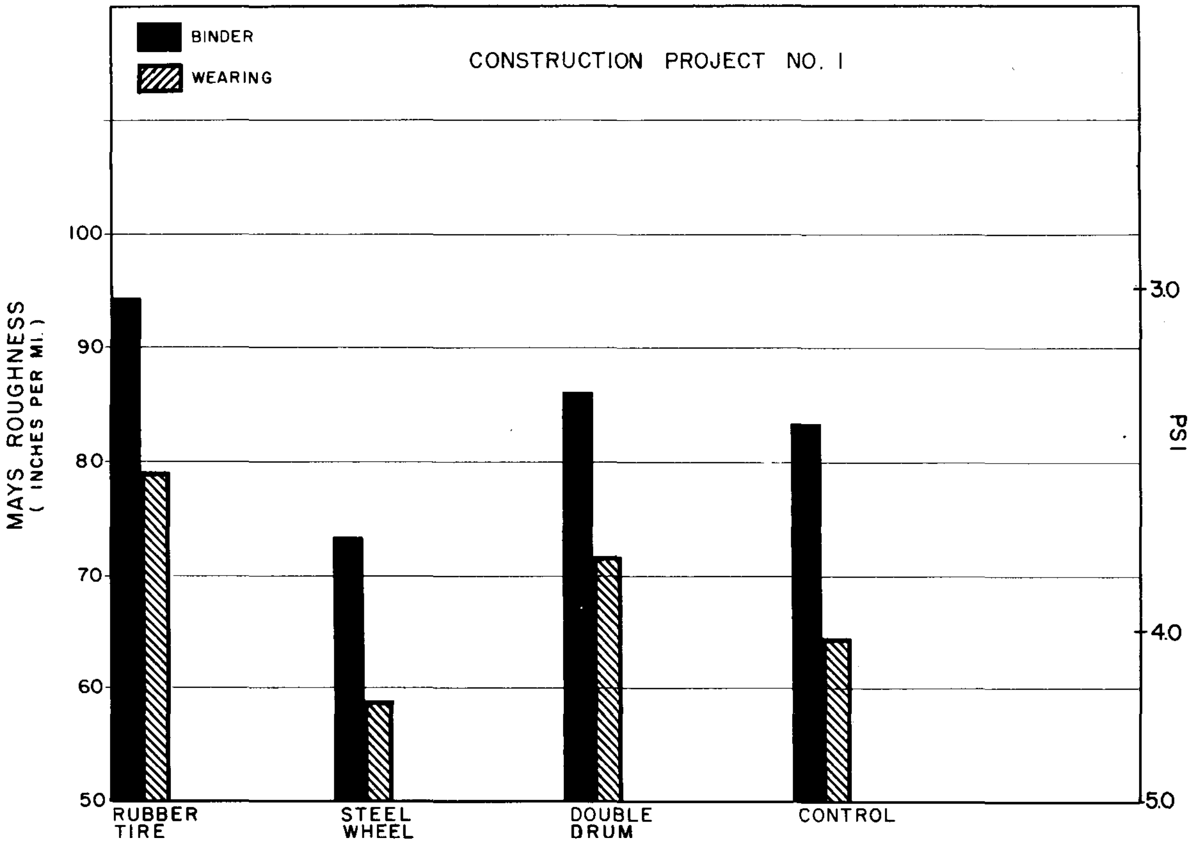


Figure 9 - Surface Roughness for Individual Test Sections



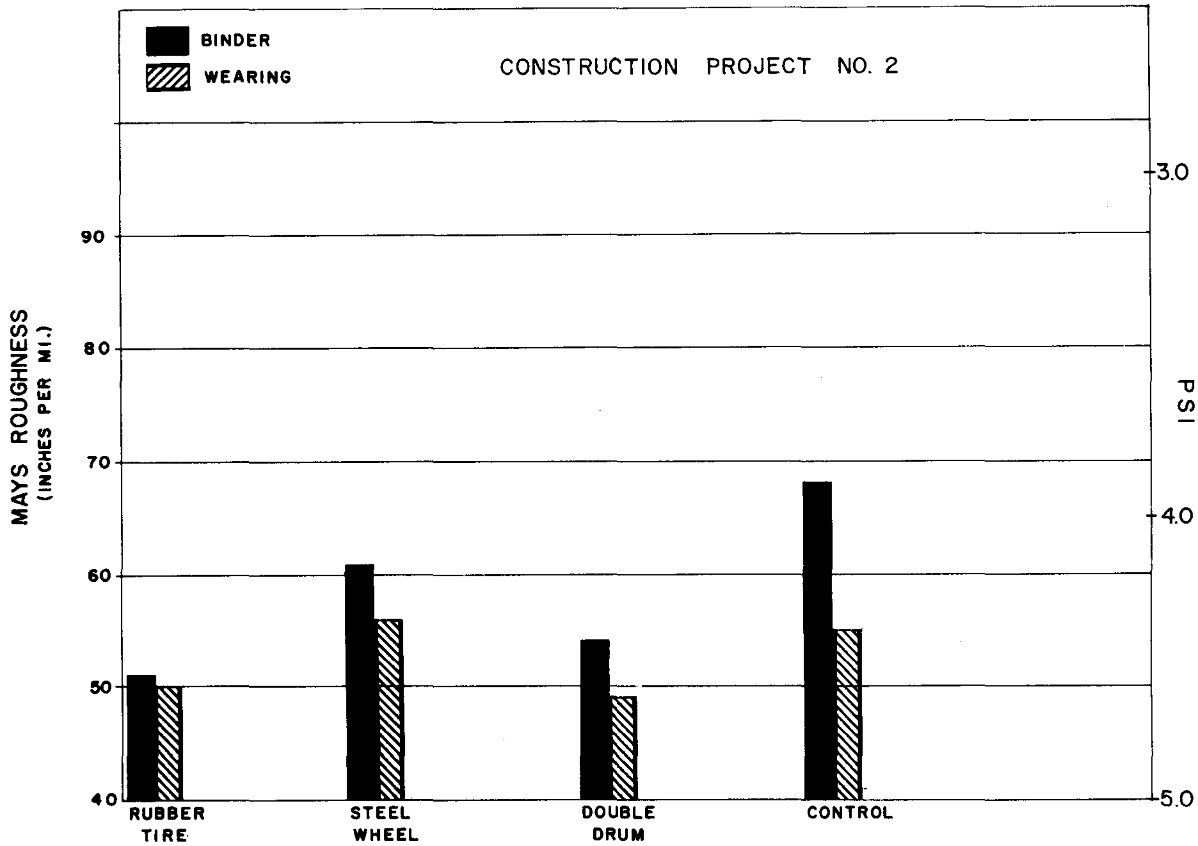


Figure 10 - Surface Roughness for Various Roller Groups

rollers versus conventional rollers is best illustrated in Figure 10. When the data is grouped under various roller types, it can be seen that results produced on Project No. 1 indicate close comparison between control and vibratory rolling. Project No. 2 results reveal that Mays Ridemeter measurements were slightly lower for vibratory compaction than for conventional rolling. Overall, however, the differences in findings for both projects are negligible, suggesting that vibratory rollers are capable of producing surfaces with a riding quality equal to conventional compaction methods.

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 these particular projects may have been the result of the paving operations or imperfections in the old surfaces and not necessarily the compaction process. The ripples were more visible 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 these projects. However, surface imprints or wheel marks could be viewed during and immediately following rolling operations. Imprints were somewhat more noticeable 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 courses 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 these projects 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 used on construction Project No. 1 had little or no difficulty maintaining the pace of the paving operation. A full day's production normally accounted for about 1500 tons (1.36 E6 Kg.) of mix. The decreased 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. Table 5 gives an indication of compaction times and rates for the various rollers on the wearing courses of these particular projects.

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 research project and should not be mistaken to be representative of maximum output. The controlling factor in most cases was the speed of the paving

Table 5

AVERAGE RATES OF COMPACTION

Roller Name	Const. Proj.No.	Average Rolling Time (min.-sec.)	Average Rolling Distance (ft.)	Average Rate per 100 ft.(30.5 m) of lane (min.)
Rex SP-900	1	8 - 20	230	3.62
Bros SWV-7355V	1	8 - 15	500	1.65
	2	7 - 24	335	2.21
Raygo Rustler 404-B	1	11 - 0	400	2.75
	2	9 - 36	370	2.59
Dynapac CC 42A	1	9 - 15	300	3.08
	2	13 - 12	379	3.48
Buffalo Bomag BW-210	1	6 - 0	270	2.22
	2	-	-	-
Tampo 166A	1	6 - 45	400	1.69
Galion VOS-84	1	-	-	-
	2	14 - 48	380	3.89
Hyster C-625A	2	8 - 24	300	2.80
Conventional Rollers	1	13 - 45	288	4.77
	2	42 - 0	800	5.25

Average rate of compaction for vibratory rollers = 2.73 min. per 100 ft.

Average rate of compaction of conventional rollers = 5.01 min per 100 ft.

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; 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 which in turn can reduce pavement density. One instance of this was noted on the binder course of Construction Project No. 1. 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 supported by the results of this research study.

1. Relative pavement densities produced by vibratory rollers compare favorably with densities obtained from conventional rolling.
2. Surface smoothness measurements determined by the 10-foot (3.0 m) rolling straightedge and the May's Ridemeter indicate that pavements compacted with vibratory rollers are similar in smoothness to pavement sections rolled with conventional equipment.
3. Variability in pavement densities was slightly greater for vibratory compacted sections of pavement than for sections compacted with static weight rollers.
4. Vibratory rollers required fewer passes to achieve maximum, pavement density than did conventional static weight rollers.
5. No correlation was found to exit between compacted roadway densities and aggregate gradations determined by percent passing the No. 4 and No. 40 sieves
6. Vibratory rollers operated in a static mode produced lower roadway densities than when operated in a vibratory mode.
7. Performance of the various vibratory rollers tested is largely dependent upon rolling methods and operator experience.
8. The general appearance of a surface compacted with a vibratory roller was equal in quality to the appearance of a surface rolled with conventional static weight rollers.

RECOMMENDATIONS

On the basis of findings obtained from this research project indicating that vibratory rollers are capable of compacting asphaltic concrete pavements to a relative density and surface smoothness required by end result specifications, it has been recommended that Department specifications be amended to permit the use of vibratory rollers on all hot mix construction projects. As stated under Implementation, the Department has already adopted this recommendation and has revised its specifications accordingly (see Appendix).

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

1. Density growth criteria for various thicknesses of asphaltic concrete to establish optimum rolling patterns, speed, number of passes, static weights, frequencies of vibration and amplitudes.

2. Effects of vibratory compaction over underlying courses with high water tables typical of Louisiana conditions.

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

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

APPENDIX

APPENDIX

1. Specifications for bituminous concrete mixture.
2. Construction Project No. 1 Results.
    a. Gradation data for binder course.
    b. Gradation data for wearing course.
    c. Roadway data for binder course.
    d. Roadway data for wearing course.
3. Construction Project No. 2 Results.
    a. Gradation data for binder course.
    b. Gradation data for wearing course.
    c. Roadway data for binder course
    d. Roadway data for wearing course.
4. Recommended Supplemental Specifications for Rollers

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
CONSTRUCTION PROJECT NO. 1

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
CONSTRUCTION PROJECT NO. 1

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

CONSTRUCTION PROJECT NO. 1

OBS	SECTN	RT	FROM STA	TO STA	LN	VPASS	NV	AVGDV	SDV	MINDV	MAXDV	TOL10H	TOL10L	TOL15H	TOL15L	RI
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	95
2	01EXP	RE	1077+95	1031+00	LF	VIBRT11	8	96.2	0.96	95.5	97.9	.12	0.41	1.38	4.65	74
3	02CON		976+76	933+00	RT	83P20T3	6	97.4	1.22	95.3	98.3	.22	0.57	1.05	2.26	75
4	02CON		976+76	933+00	LT	83P20T3	8	97.1	0.76	96.0	98.5	.18	0.30	0.60	2.54	79
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	72
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	71
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	91
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	92
9	05EXP	VP	747+00	707+00	LF	VIBRT11	6	93.7	1.77	90.7	96.2	.19	0.00	0.76	3.39	98
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	92
11	06EXP	BU	704+00	665+32	LF	VIBRT 9	7	94.6	0.93	92.9	95.9	.00	0.57	1.18	2.69	83
12	06EXP	BU	704+00	665+32	RT	VIBRT 9	7	94.3	1.20	92.3	96.2	.23	0.64	0.82	3.88	67
13	07CON		622+50	660+00	RT		5	96.6	0.46	96.2	97.4	.00	1.29	0.07	5.24	85
14	08EXP	GA	616+00	570+35	LF	VIBRT 7	9	95.1	0.40	94.4	95.5	.65	1.59	1.09	3.69	102
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	111
16	09EXP	TA	567+	526+20	RT	VIBRT 9	6	96.8	0.85	95.3	97.6	.01	0.19	0.25	1.43	85
17	09EXP	TA	567+	526+20	LF	VIBRT 9	6	96.5	0.62	95.3	97.4	.13	0.67	0.18	1.06	68
18	10CON		516+79	504+50	RT		3	96.6	0.75	95.7	97.0	.22	0.60	0.51	1.57	86
19	10CON		516+79	504+50	LF		3	98.0	1.05	97.0	99.1	.15	0.65	0.85	1.46	85

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

CONSTRUCTION PROJECT NO. 1

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	95.9	1.95	90.1	96.1	.25	1.09	.36	2.61	108	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	83P09T5	8	97.3	1.02	96.1	99.1	.05	0.06	.13	0.42	54	4.77		
4	02CON		976+76	933+00	LT	83P09T5	8	96.0	0.97	94.4	97.4	.05	0.36	.20	2.04	65	4.77		
5	03CON		891+50	832+00	RT	83P09T5	8	95.6	0.65	94.4	96.6	.01	0.09	.03	0.35		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	60	2.75	3	95.6
8	04EXP	RA	789+50	749+50	LT	5	8	96.5	0.85	94.6	97.4	.00	0.50	.00	3.13	69	2.75	3	95.4
9	05EXP	VI	746+00	707+00	RT	6	8	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	8	95.7	1.31	93.9	97.4	.27	1.87	.44	5.96	92	3.06		
11	06EXP	BU	704+00	665+32	RT	7	8	96.6	0.65	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	83P09T5	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	83P09T5	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	8	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.

BINDER COURSE MIX DESIGN AND EXTRACTED GRADATION DATA
CONSTRUCTION PROJECT NO. 2

DATE	TIME	SPGR	THEO	STAB	FLOW	BIN1	BIN2	BIN3	BIN4	MF	AC	CRSH	P34IN	P12IN	NO4	NO10	NO40	NO80	NO200	ACEXT
11/21/74	AM	2.38	2.47	1821	10	43.0	25.5	18.6	6.7	2	4.2		93	81	47	40	24	12	6	4.3
11/21/74	PM	2.38	2.47	1821	10	43.0	25.5	18.6	6.7	2	4.2		99	82	44	37	22	11	7	4.3
11/22/74	AM	2.38	2.46	1789	8	46.0	21.8	21.0	5.0	2	4.2		98	82	44	36	20	10	6	4.4
11/22/74	PM	2.38	2.46	1789	8	46.0	21.8	21.0	5.0	2	4.2		100	84	44	36	21	11	6	4.1
11/23/74	AM	2.38	2.46	1742	8	46.0	21.8	21.0	5.0	2	4.2		100	88	49	41	24	13	7	4.4
11/23/74	PM	2.38	2.46	1742	8	46.0	21.8	21.0	5.0	2	4.2		99	82	51	43	25	12	7	4.0
11/26/74	AM	2.38	2.46	1784	9	46.0	21.8	21.0	5.0	2	4.2		100	88	53	45	27	13	7	4.6
11/26/74	PM	2.38	2.46	1784	9	46.0	21.8	21.0	5.0	2	4.2		98	84	47	37	23	12	7	3.9
22/21/74	AM	2.37	2.46	1694	8	46.0	21.8	21.0	5.0	2	4.2		99	82	45	39	23	11	6	4.0
11/27/74	PM	2.37	2.46	1694	8	46.0	21.8	21.0	5.0	2	4.2		100	87	46	40	24	11	6	4.1
06/23/75	AM	2.33	2.45	1170	6	44.4	18.0	20.3	10.7	2	4.6	77	100	86	45	37	20	8	5	4.4
06/23/75	PM	2.33	2.45	1170	6	44.4	18.0	20.3	10.7	2	4.6	76	100	88	61	53	28	12	8	4.0
06/25/75	AM	2.36	2.46	1757	6	41.8	15.9	18.0	18.1	2	4.2	76	100	88	55	46	25	11	6	4.0
06/25/75	PM	2.36	2.46	1757	6	41.8	15.9	18.0	18.1	2	4.2	77	100	86	52	44	24	12	7	3.9
06/26/75	AM	2.34	2.46	1435	10	41.8	15.9	18.0	18.1	2	4.2	79	100	90	52	42	23	12	7	4.0
06/26/75	PM	2.34	2.46	1435	10	41.8	15.9	18.0	18.1	2	4.2	83	100	89	57	48	25	11	7	3.9

N=16

ABBREVIATIONS

SPGR - Specific gravity of laboratory briquette.
THEO - Theoretical Specific Gravity.
STAB - Marshall stability (lbs.).
BIN( ) - Bin percentages of aggregates.
MF - Mineral filler percentage.
AC - Asphalt content (%)
CRSH - Percent of crushed aggregate retained on No. 4 Sieve.
P( ) - Percent of aggregate passing designated sieve.
ACEXT - Percent of extracted asphalt.

WEARING COURSE MIX DESIGN AND EXTRACTED GRADATION DATA

CONSTRUCTION PROJECT NO. 2

DATE	TIME	SPGR	THEO	STAB	FLOW	BIN1	BIN2	BIN3	BIN4	MF	AC	CRSH	P34IN	P12IN	NO4	NO10	NO40	NO80	NO200	ACEXT
07/03/75	AM	2.36	2.44	1519	10	42.0	19.2	20.6	10.4	3	4.8	82	100	98	67	54	28	13	8	4.9
07/03/75	PM	2.36	2.44	1519	10	42.0	19.2	20.6	10.4	3	4.8	79	100	93	57	47	26	12	8	4.7
07/07/75	AM	2.36	2.44	1675	12	42.0	19.2	20.6	10.4	3	4.8	82	100	92	59	48	25	11	7	4.7
07/07/75	PM	2.36	2.44	1675	12	42.0	19.2	20.6	10.4	3	4.8	82	100	92	56	45	24	11	6	4.4
07/09/75	AM	2.36	2.44	1630	11	42.0	19.2	20.6	10.4	3	4.8	81	100	94	57	47	28	12	7	5.0
07/09/75	PM	2.36	2.44	1630	11	42.0	19.2	20.6	10.4	3	4.8	81	100	86	50	40	24	10	6	4.2
07/11/75	AM	2.35	2.44	1722	6	42.0	19.2	20.6	10.4	3	4.8	79	100	90	51	42	24	10	6	4.5
07/11/75	PM	2.35	2.44	1722	6	42.0	19.2	20.6	10.4	3	4.8	79	100	94	58	48	25	11	6	4.8
06/27/75	AM	2.36	2.46	1259	10	41.8	15.9	18.0	18.1	2	4.2	72	100	92	54	45	25	11	7	3.8
6/27/75	PM	2.36	2.46	1259	10	41.8	15.9	18.0	18.1	2	4.2	72	100	87	53	43	22	9	5	4.4
06/28/75	AM	2.36	2.44	1414	10	42.0	19.2	20.6	10.4	3	4.8	85	100	90	60	49	25	11	7	4.7
06/28/75	PM	2.36	2.44	1414	10	42.0	19.2	20.6	10.4	3	4.8	85	100	93	56	47	24	10	6	4.3

N=12

ABBREVIATIONS

SPGR - - Specific gravity of laboratory briquette.
THEO - Theoretical Specific Gravity.
STAB - Marshall stability (lbs.).
BIN( ) - Bin percentages of aggregates.
MF - Mineral filler percentage.
AC - Asphalt content (%)
CRSH - Percent of crushed aggregate retained on No. 4 Sieve.
P( ) - Percent of aggregate passing designated sieve.
ACEXT - Percent of extracted asphalt.

BINDER COURSE ROADWAY DATA FOR COMPACTION & SURFACE SMOOTHNESS

CONSTRUCTION PROJECT NO. 2

SEC_NO	ROLL	FROMSTA	TO_STA	VPASS	N	MEAN	STD	MIN	MAX	TOLHRT	TOLHLT	TOLLRT	TOLLLT	RI_RT	RI_LT	TIME
01CON		435+00	461+20	B5P15T3	10	95.5	1.94	91.6	98.7	.54	.35	1.31	1.77	64	72	5.94
02EXP	RAY	466+74	501+50	VIBRT05	13	96.0	1.05	93.7	97.1	.00	.05	0.19	0.05	39	47	2.60
03EXP	GAL	519+13	569+00	VIBRT09	19	93.9	1.69	91.2	96.2	.05	.00	0.03	0.00	35	44	3.91
04EXP	VPD	570+03	611+85	VIBRT09	19	95.6	1.45	92.9	98.3	.15	.18	1.31	0.62	53	56	3.46
05EXP	BUF	613+20	642+00	VIBRT09	12	95.8	1.53	94.5	97.5	.07	.44	0.10	0.50	57	67	
06CON		664+00	760+00	B5P15T3	38	96.7	1.48	94.0	99.6	.28	.07	0.41	0.12			5.94
07EXP	BRO	764+00	817+10	VIBRT05	17	97.2	1.06	95.3	98.7	.02	.02	0.15	0.18	59	61	2.21
08EXP	HYS	819+60	855+00	VIBRT05	15	96.4	1.30	94.0	98.7	.00	.07	0.46	0.28	74	70	2.80

N=8

ABBREVIATIONS

SEC NO	-	Description of experimental section.
ROLL	-	Roller name abbreviated.
VPASS	-	Total number of roller passes.
N	-	Time (min.) to complete one coverage.
MEAN	-	Average density (% lab. biguette)
STD	-	Standard deviation of sample.
MIN	-	Minimum core density.
MAX	-	Maximum core density.
TOLHRT	-	Percent of right lane exceeding tolerance.
TALALT	-	Percent of left lane exceeding tolerance.
RIRT	-	Mays Ridemeter roughness right lane (in. per mi.)
RILT	-	Mays Ridemeter roughness left lane (in. per mi.)
TIME	-	Time (min.) to compact 100 linear ft. of pavement.

WEARING COURSE ROADWAY DATA FOR COMPACTION & SURFACE SMOOTHNESS

CONSTRUCTION PROJECT NO. 2

SEC_NO	ROLL	FROMSTA	TO_STA	VPASS	N	MEAN	STD	MIN	MAX	TOLHRT	TOLHLT	TOLLRT	TOLLLT	RI_RT	RI_LT	TIME
01CON		435+00	461+20	B5P15T3	12	96.4	1.08	94.9	98.7	.09	.00	.10	.00	60	60	5.94
02EXP	RAY	466+74	501+50	VIBRT05	13	97.0	0.79	95.3	97.9	.00	.00	.00	.00	54	47	3.10
03EXP	GAL	519+00	569+00	VIBRT38	19	95.9	1.06	93.2	97.5	.13	.00	.00	.00	46	42	3.37
04EXP	VPD	571+00	600+00	VIBRT09	12	95.3	1.11	93.2	97.0	.02	.00	.10	.00	51	47	2.16
05EXP	BUF	613+20	642+00	VIBRT05	12	96.3	1.11	93.6	97.9	.00	.00	.08	.03	55	61	3.90
06CON		664+00	760+00	B5P15T3	40	95.8	1.21	93.2	98.7	.00	.01	.06	.01	51	49	5.94
07EXP	BRO	764+00	817+10	VIBRT05	21	96.7	1.20	94.5	98.7	.00	.00	.02	.00	46	42	2.21
08EXP	HYS	819+60	855+00	VIBRT05	15	95.7	2.00	92.8	98.3	.00	.00	.00	.00	55	55	2.36

N=8

ABBREVIATIONS

SEC NO - Description of experimental section.
ROLL - Roller name abbreviated.
VPASS - Total number of roller passes.
N - Time (min.) to complete one coverage.
MEAN - Average density (% lab. biguette)
STD - Standard deviation of sample.
MIN - Minimum core density.
MAX - Maximum core density.
TOLHRT - Percent of right lane exceeding tolerance.
TALALT - Percent of left lane exceeding tolerance.
RIRT - Mays Ridemeter roughness right lane (in. per mi.)
RILT - Mays Ridemeter roughness left lane (in. per mi.)
TIME - Time (min.) to compact 100 linear ft. of pavement.

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 enought 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.