

A HOT-MIX ASPHALT COMPACTION DEMONSTRATION
EXPERIMENT COMPARING VIBRATORY AND
CONVENTIONAL ROLLERS

LAST COPY
DO NOT REMOVE FROM LIBRARY



MICHIGAN DEPARTMENT OF STATE HIGHWAYS

A HOT-MIX ASPHALT COMPACTION DEMONSTRATION
EXPERIMENT COMPARING VIBRATORY AND
CONVENTIONAL ROLLERS

C. A. Zapata

Research Laboratory Section
Testing and Research Division
Research Project 73 C-15
Research Report No. R-885

Michigan State Highway and Transportation Commission
E. V. Erickson, Chairman; Charles H. Hewitt,
Vice-Chairman, Carl V. Pellonpaa, Peter B. Fletcher
Lansing, October 1973

ACKNOWLEDGEMENTS

The author wishes to thank the following persons for their cooperation during this compaction demonstration project. Arvid R., and Thomas A. Hicks of the Hicks Co.; Alfred Chritz, Larry Haskel, Fred Carrier from the MDSHT Testing Laboratory; Jack DeFoe, Merlin Tiedt, Leo Bateman, Anthony Bryhan, Lawrence Parr, and Frederick Cassel of the Highway Research Laboratory.

The information contained in this report was compiled exclusively for the use of the Michigan Department of State Highways. Recommendations contained herein are based upon the research data obtained and the expertise of the researchers, and are not necessarily to be construed as Department policy. No material contained herein is to be reproduced--wholly or in part--without the expressed permission of the Engineer of Testing and Research.

INTRODUCTION

To determine the best way to obtain compaction in asphalt pavements, the Department frequently engages in testing different compaction equipment, including vibratory rollers. In July 1969, a brief compaction study comparing vibratory and conventional rollers was conducted while repairing a concrete pavement. It was reported that better compaction was obtained with the conventional than with the vibratory roller. Subsequently, during the 1972 construction season, a second comparative compaction study between vibratory and conventional rollers was conducted over bituminous leveling and wearing courses. This study indicated that more rolling passes were required with the vibratory than with the conventional roller to obtain acceptable compaction. A similar project was set up by using the same type of vibratory roller but with its pneumatic tires encased in steel cylinders. The results showed slightly better compaction performance for the vibratory over the conventional roller (1). The compaction study that is described in this report is a continuation of this testing program.

Although the use of vibratory compaction rollers on asphalt concrete courses has been limited, highway agencies in California, Virginia, Florida, and others, are presently testing vibratory rollers in both breakdown (initial) and finish rolling. Limited information from these experiments indicates that vibratory rollers, operating properly, are capable of producing acceptable densities with fewer passes than conventional rollers (1). However, more experience with the operational performance of these compactors is needed to estimate their full potential in compacting bituminous surfaces (2, 3).

The compaction study that follows is intended to evaluate the relative performance of a vibratory roller compared with a conventional steel-wheeled type used in asphalt pavement construction. It is designed to achieve two main objectives: 1) To provide construction data and experimental results by which relative compaction performance of the two types of rollers may be simultaneously evaluated; 2) To recommend where additional efforts are needed to obtain more economical, acceptable compaction. Moreover, in attaining these objectives, it was important to establish some workable ground rules for properly conducting the experiment without interfering with regular inspection and construction procedures.

The validity of the study is based on two main assumptions: 1) That the structural foundation of the test sections constructed for this experiment is sufficiently uniform to prevent any detrimental densification or differential expansion while supporting the pavement under test; and, 2) that the influence of other construction variables such as asphalt mix materials and characteristics, plant production, and hauling operations are minimized by regular inspection and control practices conducted under normal job control.

M 18 COMPACTION PROJECT

The construction project (Mb 26011) used in this study consisted of resurfacing 4.6 miles of an existing concrete pavement with a bituminous bond coat and Bituminous Aggregate Pavement (MDSHT Standard Spec. 4.11). The existing concrete pavement, constructed in 1941, was 22 ft wide with a 9-7-9-in. cross-section located on M 18 between Burgess and Wood Rds, south of Gladwin in Gladwin and Clare Counties. The traffic on this route has increased during the last 32 years from 558 to 3,200 vehicles per day. The original pavement was badly scaled and cracked, with bituminous patches covering most of the transverse joints. Figure 1 shows the pavement distress conditions before being rehabilitated with the asphalt overlay.

The construction project was reviewed and analyzed to clarify the work to be performed. Before paving operations began, a general agreement on how to conduct the study was negotiated with the contractor, and he was furnished with a detailed plan of the experiment, including the important construction variables to be measured. Before paving operations began, an agreement was reached with the contractor that:

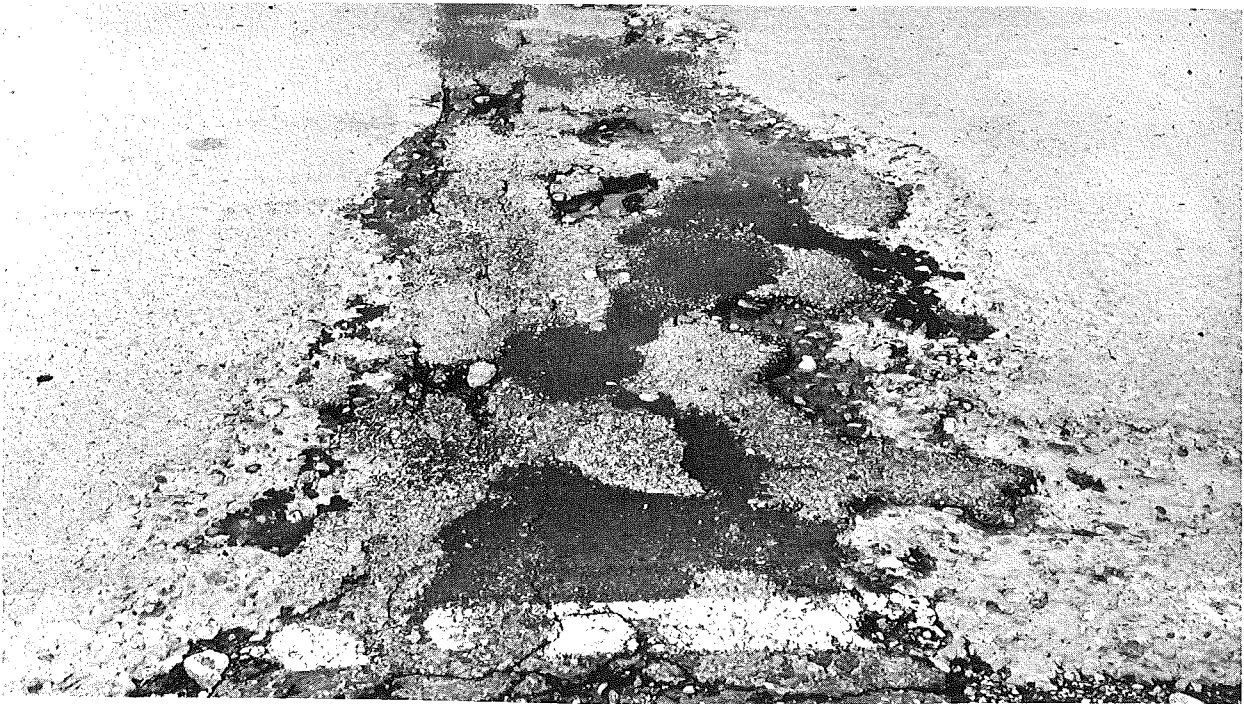
- 1) One straight mile of two-lane pavement was divided into eight, 1,000 ft long test sections, two abreast, with transitions between sections for changing compaction rollers (Fig. 2). All test sections were to be completed the same day.

- 2) According to the objectives of the experiment, the contractor should be allowed to use his own compaction methods and steel rollers to obtain the required density with the least compacting effort, if possible.

- 3) The randomized sampling and testing for the one mile test area should be conducted by the Research Laboratory personnel without interfering with the regular inspection and construction procedures.



Sta. 227 looking south from the outside shoulder.



Sta. 237 looking west from the outside shoulder.

Figure 1. Typical distress conditions of the original 32 year old concrete pavement, Construction Project Mb 26011, M 18 South of Gladwin.

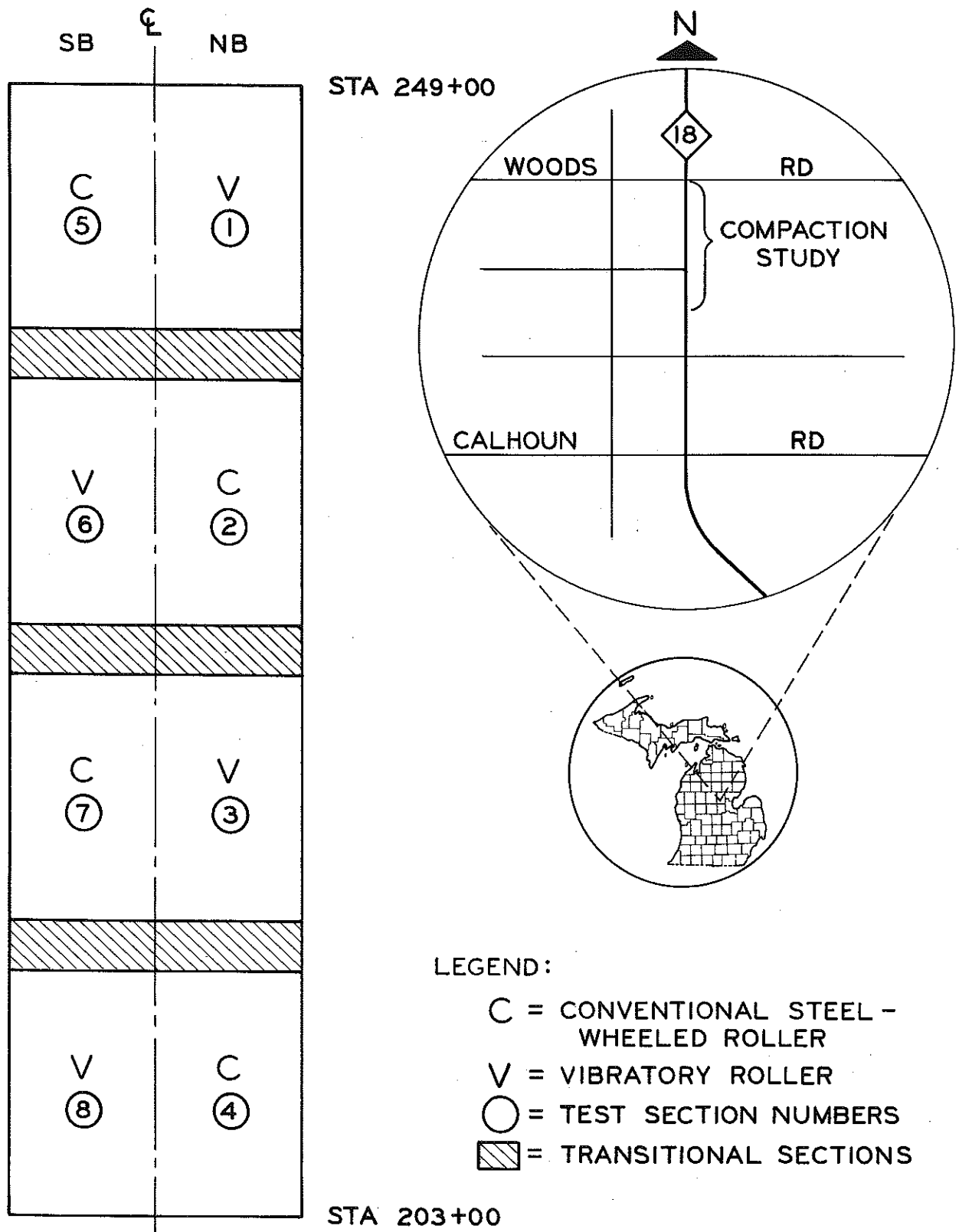


Figure 2. Experimental layout comparing vibratory and conventional compaction over one mile of two-lane highway. The test area was divided into eight 1,000-ft sections.

Hot-Mix Bituminous Surfacing

The bituminous materials specified for the project consisted of a bond coat applied over the existing concrete pavement at the rate of 0.15 gal/sq yd and surfacing with Bituminous Aggregate Pavement (4.11) at the rate of 180 lb/sq yd. The surfacing mixture consisted of 20A coarse aggregate, 3MF mineral filler, and asphalt cement of 120-150 penetration grade. A portable continuous plant (848A Barber-Greene) with rated capacity of 300 tons/hr and located about seven miles north of the project was used to produce 11 tons per Station of the asphaltic mixtures. The mix was discharged into insulated 35 to 50 ton trucks and delivered to the paver at a temperature of 275 to 290 F. A Blaw-Knox paver placed the mix (about 1-3/4 in. thick, 11-ft wide) and moved at about a speed of 50 ft/minute.

Compaction Control

Requirements for compaction of asphalt mixtures are specified in the MDSHT Construction Manual (p. 456). The vibratory roller man was free to manipulate his roller as he wished. On the other hand, the conventional roller man was required to follow MDSHT conventional rolling pattern (Fig. 3). The conventional rolling pattern behind the paver may include the initial or breakdown rolling with steel-wheeled rollers, the second or intermediate rolling with pneumatic-tired rollers, and the final rolling with steel-wheeled tandem rollers.

Figure 3 also shows the two steel tandem rollers made available by the contractor. The conventional steel roller, an 8 to 12 ton Galion with rated surface pressure up to 272 lb/lin in. of rolling width operated at 2.8 mph. The vibratory roller, a Vibro-Plus CC-42A with rated surface pressure up to 507 lb/lin in. of rolling width, operated at 3.0 mph. While compacting at 2,400 vpm (vibrations per minute) and low amplitude during initial and intermediate rolling, it was delivering impacts 1.3 in. apart on the asphalt surface. Final rolling was completed with static or non-vibrating passes. The general characteristics of both compaction units are summarized in Appendix B.

Compaction control conducted by Testing and Research personnel included:

- 1) Negotiating the degree of inspection required to ascertain uniform compaction operations representative of what is practical and acceptable construction. This step was essential for proper comparative analysis between the two rollers.

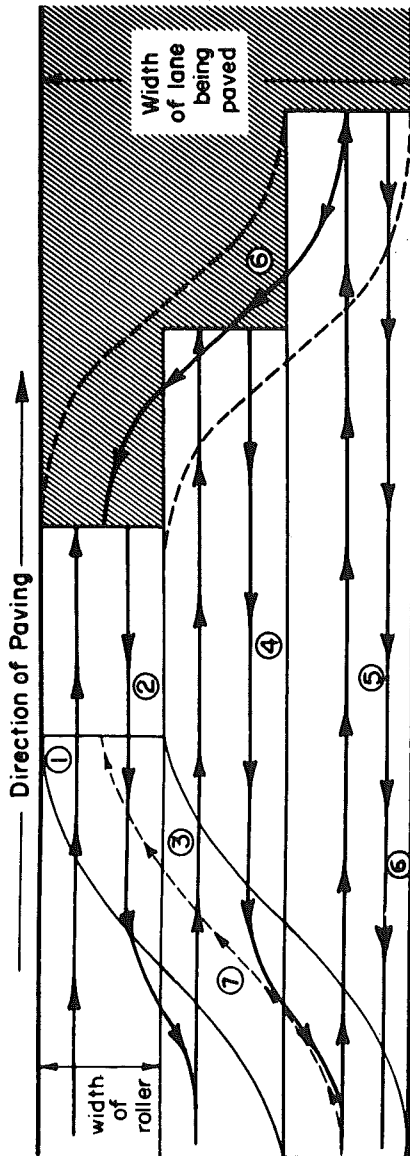
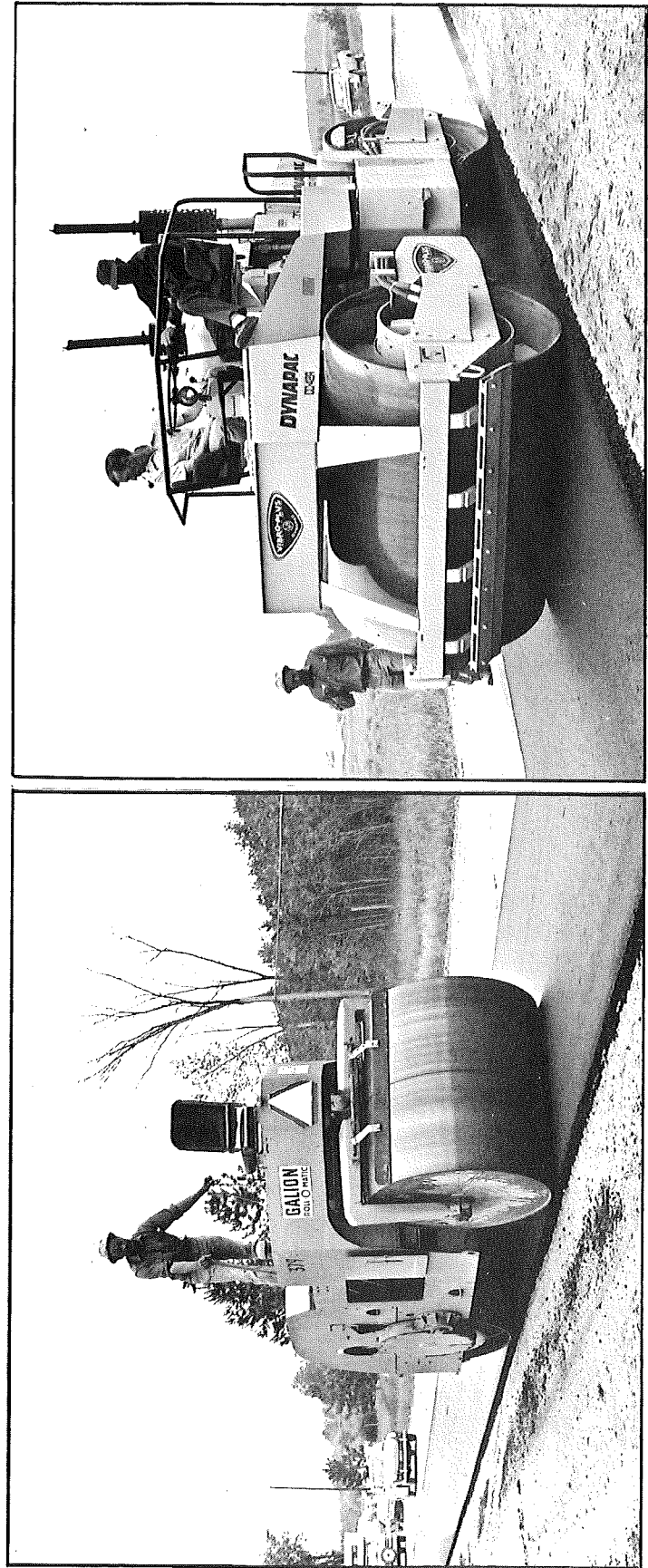


Figure 3. MDSHT conventional rolling pattern (left) and the two compaction units used in the experiment. The conventional steel-wheeled roller at bottom left and the vibratory roller at bottom right.

This is a recommended rolling pattern. Every pass of the roller should proceed straight into the compacted mix and return in the same path. After the required passes are completed, the roller should move to the outside of the pavement on cooled material and repeat the procedure. A second method shown is to move to the outside across the ends of the previous passes. This requires turning on the hot mix, however, and the first method is preferred.



2) Attempting to secure continuous spreading operations on all test sections. Changing from one roller to the other was restricted to the transitional areas of the road. Starting in the northbound lane, paving operations proceeded from north to south (Fig. 2). Each section was separated from adjacent sections and transitional areas by traffic cones placed on the shoulders.

3) Checking thickness of the asphalt layer and measuring laydown temperatures, at frequent intervals.

4) Measuring rolling temperatures at random locations and recording the number of roller passes in each section.

5) Checking paver and roller speeds at frequent intervals. Rolling continued until the operator decided that compaction was complete.

6) Taking nuclear density readings at random on the centerline of the finished lane before it was opened to traffic. The same random locations were selected for Laboratory test samples by coring the compacted surface.

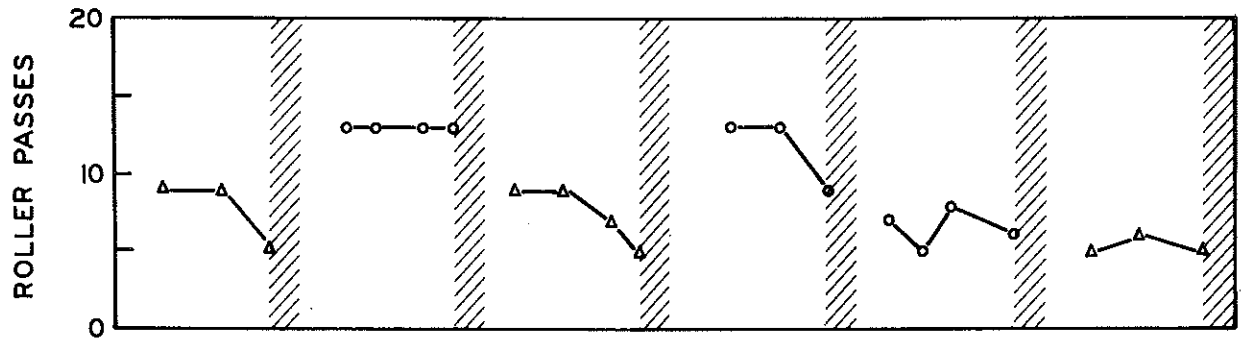
Construction Problems

Certain construction difficulties arose during the course of the project and are listed below.

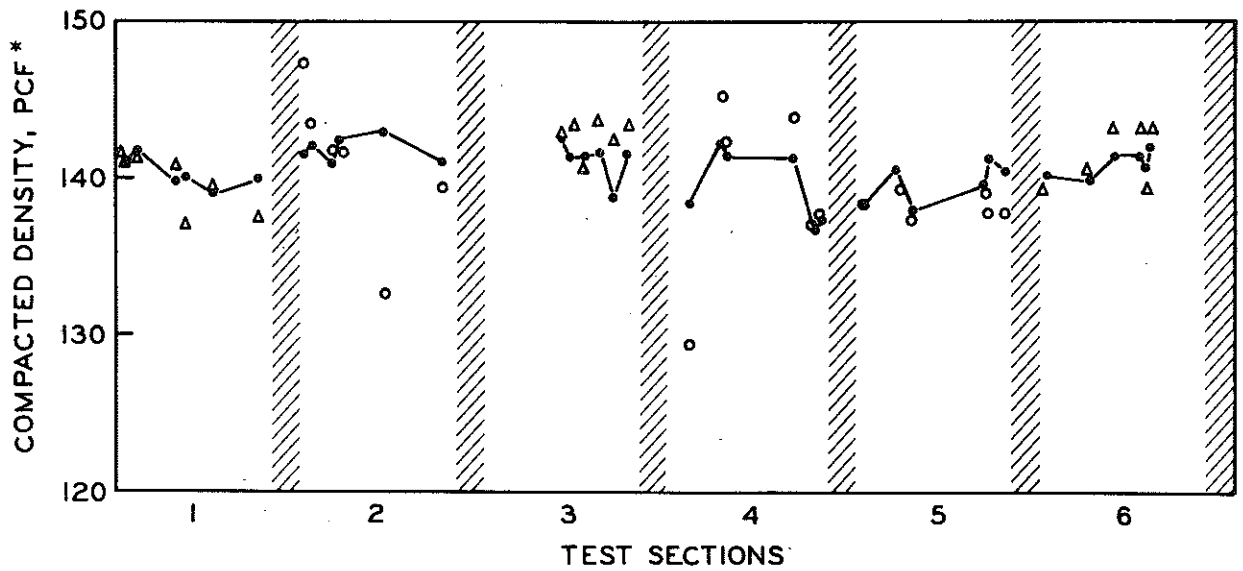
1) The roller operator experienced some difficulty in adequately timing the initial and final rolling. In many instances, he refrained from initial rolling until a so-called 'blue smoke' disappeared from the wearing course. In others, he began the final rolling when the asphalt mat cooled down to a temperature between 130 and 140 F. The weather was cloudy with temperatures ranging from 67 to 80 F, and wind velocities from 5 to 10 mph.

2) Although the compaction operation was required to be straight, smooth, and continuous for the full length of each test section, in practice this was not attained. Frequently, the rollers operated in wavy lines and with jerky reverse motions after reaching a maximum length of about 400 ft. These variations made recording the roller passes a difficult task.

3) At times, decompaction waves (or ripples) were noticeable in front of and behind the conventional roller, especially after the breakdown or initial rolling. Also, when compaction was completed, fine cracks were noted over some transverse joints.



Note: Each point (up to four per section) represents the number of roller passes needed to complete compaction at the location shown.



LEGEND:
 Δ = VIBRATORY
 ○ = CONVENTIONAL
 ● = LAB. CORE DENSITY
 // = TRANSITIONAL LENGTH

*In-place compacted densities (vibratory and conventional) determined with a nuclear gage. For each compaction method, six random points were obtained per section.

Figure 4. Roller passes needed to complete compaction and compacted densities obtained on test area.

4) Due to problems in bituminous production, Test Sections 7 and 8 were not completed according to the experimental layout (Fig. 2). Therefore, those two sections were not included in the study. The first six sections were completed in six hours in the same day according to plan.

5) An attempt to obtain a density growth curve was made with a nuclear density gage, but it was discontinued to assure compliance with the ground rules initially established.

In general, the construction problems were not sufficiently serious to invalidate the method used to appraise the compaction performance of the two rollers.

Riding Quality

Two weeks after the test sections were constructed, riding quality measurements were obtained with the GM Rapid Travel Profilometer. The results indicated that similar surface smoothness or riding quality was achieved over the test sections.

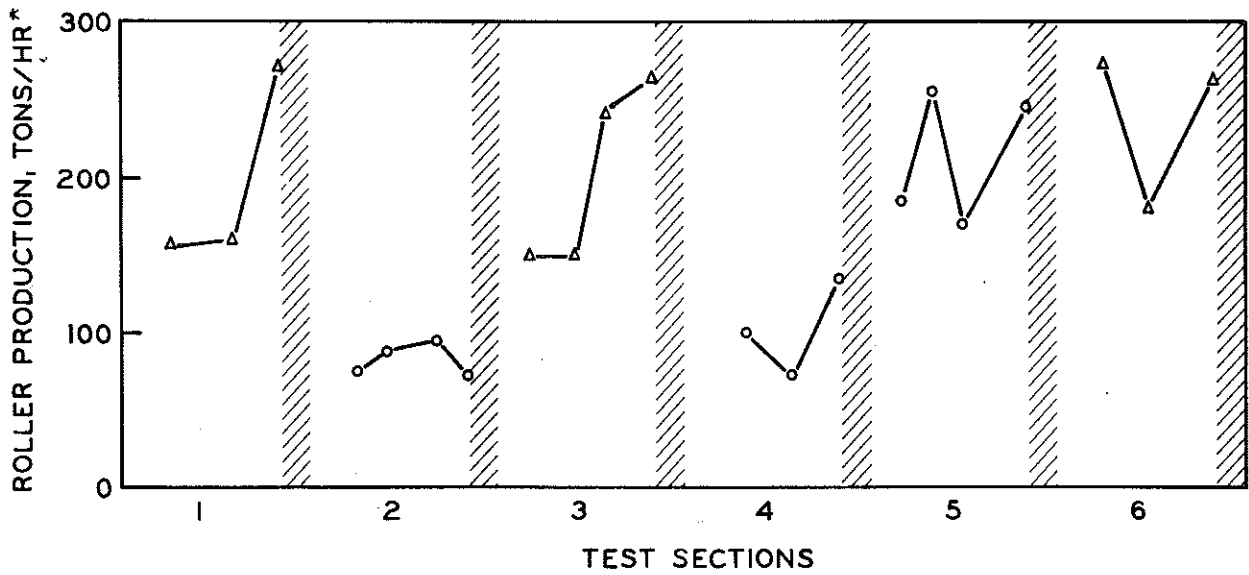
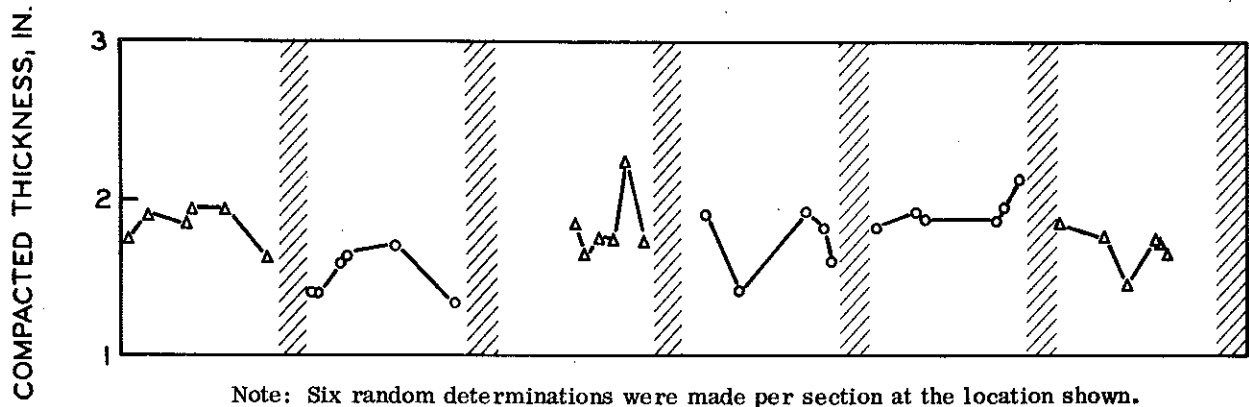
DISCUSSION OF RESULTS

Since the primary objective of the experiment was to compare the performance of two compaction rollers, the discussion will be confined to the results of in-place compacted density, thickness of the bituminous surfacing mixture, and roller productivity and efficiency. Field and laboratory data are summarized in Table 1 and presented graphically in Figures 4 and 5.

After the rollerman decided when rolling was completed, both nuclear and core density determinations were made. Six randomly located density tests were made in each section with a Troxler nuclear density gage. The same random locations were used to core the pavement for Marshall density tests and compacted thicknesses.

The compaction data indicate the following:

1) The vibratory test sections required fewer roller passes than the conventional sections to achieve practically the same compacted density (Fig. 4). In fact, seven passes with the vibratory roller produced a compacted density of about 140 pcf. Apparently, the same density was achieved after ten passes with the conventional roller (Table 1). It is possible that



* Computed by using Eq. (2) shown in the Appendix.
 Each point (up to four per section) represents roller productivity when compaction was completed at the location shown.

LEGEND:
 Δ = VIBRATORY
 ○ = CONVENTIONAL
 // = TRANSITIONAL LENGTH

Figure 5. Compacted thicknesses and roller production obtained on test area.

TABLE 1
SUMMARY OF COMPACTION DATA
(Bituminous Aggregate Pavement (4.11) @ 180 lb/sq yd)

Item	Nuclear Density		Laboratory Core Density		Compacted Thickness		Compaction Production	
	Vib. Roller	Conv. Roller	Vib. Roller	Conv. Roller	Vib. Roller	Conv. Roller	Vib. Roller	Conv. Roller
No. of Tests	18	18	18	18	18	18	---	---
Avg Density, pcf	141.2	139.7	140.9	140.3	---	---	---	---
Rel. Variation, %	1.6	3.0	0.8	0.9	10.0	12.6	---	---
Roller Passes	7	10	7	10	7	10	7	10
Avg Thickness, in.	---	---	---	---	1.77	1.69	---	---
No. of Sections	---	---	---	---	---	---	3	3
Avg Production, tons/hour	---	---	---	---	---	---	210	136
Roller Speed, mph	---	---	---	---	---	---	3.0	2.8

density was achieved in fewer passes, but tests were not made until the operator indicated he was through rolling.

2) Density variations, as shown by the nuclear gage, were greater in the conventional than in the vibratory test sections (Fig. 4). This was probably the result of improper rolling procedures observed while compacting conventional Sections 2 and 4 (discussed previously under 'Construction Problems').

3) As shown in Figure 4, when compared with Marshall core densities, the nuclear gage provided rapid acceptable results soon after rolling was completed.

4) Compacted thicknesses showed less relative variation in the vibratory than in the conventional sections. Again, it is quite possible that this higher relative variation in the conventionally rolled thickness could have resulted from improper rolling patterns.

5) Because of higher rolling speed and fewer roller passes to complete compaction, the vibratory roller productivity was significantly higher than that of the conventional roller.

CONCLUSIONS AND RECOMMENDATIONS

In general, this demonstration project involved two concepts which are relatively new to Michigan highway construction. The first concept was the use of a vibratory compaction method for thin bituminous layers. The results indicated that such a concept could be practical and economically feasible. It was more flexible to operate, yielded more uniform equivalent densities, required fewer roller passes, and produced an apparent smoother surface than the conventional compaction method. (However, test results with the Rapid Travel Profilometer showed similar pavement roughness for all test sections.) The second concept was the use of the nuclear density gage to determine compacted densities of the bituminous mixtures. The results indicated that such a method could be practical and economically feasible. It was easier to operate and yielded rapid and equivalent average densities when compared to the standard laboratory method. Although the agreement between the two density methods was very good, uniformity among individual values was better with the standard laboratory method. This does not mean that one method was any better than the other, but simply that there was some disagreement. Moreover, this project alone would be insufficient to evaluate the accuracy of the nuclear gage.

Based upon this investigation and on the literature survey, the vibratory compactor appears to be a reliable and worthwhile unit for use in constructing bituminous pavement. In order to gain more confidence in its use, it is suggested that a few construction projects be constructed using the vibratory compactor with the nuclear gage used for density control. A job control system similar to that tested in Virginia (4) might be effectively used for insuring adequate density.

REFERENCES

1. MDSHT Research Project File: Project No. 73 C-15.
2. Hughes, C. S., "Virginia Practice, Compaction Equipment," AAPT Proceedings, Vol. 39, 1970, pp. 661-670.
3. Santors, R. R., et al, "Stanhope Study of Compaction Methods for Bituminous Stabilized Base," Highway Research Record 385, 1972, pp. 7-18.
4. Hughes, C. S., "Methods of Compaction Control," AAPT Proceedings, Vol. 36, 1967, pp. 309-324.

5. Woods, K. B., et al, "Highway Engineering Handbook," McGraw-Hill, N. Y. C., 1960, pp. 25-4.
6. Williamson, A. O., "Raygo Rustler 404 Vibratory Roller," AIS/Const. Equipment Corp., RGS-189, 11-71 2M.

APPENDIX A

Since pavement compaction is affected by many variables, it may be appropriate to discuss some of the basic concepts related to compaction force and roller performance.

Compaction Force

Based on the Boussinesq Equation, the following simplified expression can be obtained (5):

$$\sigma_Z = 0.48 \frac{P}{Z^2} \quad (1)$$

Where σ_Z is the resulting vertical pressure, at depth Z, caused by the applied force, P, over the pavement surface. According to this expression, the resulting pressures per inch of rolling width at 1.0 and 1.7 in. below the pavement surface would be: a) 164 and 57 psi, respectively, with the vibratory roller; and b) 120 and 42 psi, respectively, with the conventional roller.

Roller Performance

To assess a roller's performance in terms of its ability to compact bituminous layers to required densities with a minimum number of passes continues to present a problem to roadbuilders. To illustrate, consider the basic production formula applied to compaction rollers (6):

$$\text{Tons/hr} = \frac{0.165 d_1 v h_i D}{N_p} \quad (2)$$

Where lane width d_1 , roller velocity v , layer thickness h_i , mixture density D , and number of passes N_p are all factors responsible for regulating roller output (tons/hr) during compaction.

In a compaction operation, the roller velocity v , and the number of passes N_p , are the two greatest concerns to the contractor. In fact, he increases productivity and profits by increasing v , and reducing N_p . On the other hand, the State Inspector is concerned with maintaining the proper interrelationship among all the factors involved in Eq. (2). Therefore, the inspector must look beyond the contractor's concern (v and N_p) and insure that the other factors are considered as well if a durable asphalt pavement that meets both design and compaction requirements is to be obtained.

Currently, because of the inability to obtain sound correlations between equipment design and properties of highway materials, compaction rollers are rated mainly by observed performance. Therefore, the optimum relationship among the factors involved in Eq. (2) is unknown. Thus, in practice, the real problem is to determine how far compaction can depart from Specifications and still obtain an acceptable compacted pavement.

APPENDIX B

CONVENTIONAL ROLLER

Mfr.: Galion
Wgt.: 8 to 12 tons
Compression: 272 lb/lin in. of rolling width
Drum width: 54 in.
Drum diam.: 60 in.
Roller Speed: 0.5 to 5.0 mph

VIBRATORY ROLLER

Mfr.: Vibro-Plus
Wgt.: 11-1/2 tons
Compression: 507 lb/lin in. of rolling width
Drum width: 66 in.
Drum diam.: 48 in.
Vibration freq.: 2,400 vpm
Roller Speed: 0 to 7.0 mph