

Commonwealth of Kentucky
Department of Highways

Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Kentucky

December 31, 1953

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MEMO TO: D. V. Terrell
Director of Research

As you know, the use of vibratory methods for the placement of screenings and the compaction of aggregates in macadam bases has received a great deal of attention throughout the country during the past few years. Various technical publications have carried articles describing the equipment and methods, but only a few have presented specific test data measuring the results achieved. Perhaps the most definite information was recorded on projects in Ohio, which by coincidence was among the first of the states investigating vibratory construction.

I understand that the initial use of a vibrator for this purpose in Kentucky was made on a macadam base in the western part of the state four or five years ago. Evidently the results that were readily apparent discouraged the contractor and engineers on the project, because vibration was discontinued after a very short trial. No attempt has been made to check this application through records of projects in that region, for probably there is no record of it with the exception of the Resident Engineer's Diary.

At any rate, discounting this early undertaking by a contractor, the first determined use of vibratory methods on a highway project in the state was made on the reconstruction of U.S. 62 between Lawrenceburg and Tyrone during the past season. Aside from the literature, there was very little background for this work although vibration had been used in the construction of a base on the Ashland Airport a few months previously, and in November, 1951, the Research Committee had received a report of observations made on a vibrated base project in Ohio*. Undoubtedly, information from these sources was helpful in the planning and letting of the project, and in determining

* "Observation of Vibratory Compaction of a Base Course," Reported to the Research Committee on December 17, 1951.

a few general procedures that would be tried at the start. However, the vibrated base was regarded as completely experimental, so the Division of Research was asked to collect and report data on the project. Accordingly our initial report prepared by Ellis G. Williams, is attached.

The report covers the macadam base construction rather thoroughly, and also discusses completion of the bituminous pavement which in itself had some experimental features introduced through the blade spreading of mixes. The blade spreading, of course, represented an attempt to eliminate irregularities and improve the riding qualities of the finished pavement.

It is evident that a single 8-inch compacted coarse of macadam can be carried out rapidly and satisfactory provided the aggregates are suitably graded for size, spread uniformly, and not subject to undesirable influences such as passing traffic before the vibratory compaction is completed. In this particular instance best results from the standpoint of surface contour were obtained when the vibrator was operated in two successive passes over the coarse stone to accomplish two different purposes. In my opinion, one pass can be sufficient if the coarse stone is placed uniformly by a commercial spreader operating on the subgrade ahead of the spread stone, rather than by a device operating over the top of the stone which it has placed.

Excessive picking, at least to the extent it was carried on this job, should not be necessary, yet the stone should have the proper section before the vibrator is used. Most important of all, traffic must be kept off until the placement of screenings is started, and the screenings must be properly graded and uniformly applied, if all the advantages of vibration are to be gained. Even with the best of conditions, the vibratory method can not accomplish much if any improvement over conventional water-bound methods so far as surface irregularities at the time of construction are concerned. On the other hand, I am certain that a base well constructed by the vibratory method is not vulnerable to settlement and rearrangement of particles within itself under the vibration of passing traffic when the pavement is in service. The water-bound macadam base is vulnerable to these changes, and hence its roughness can increase with use if the vibration from passing loads is great enough.

So far as the project in question is concerned, Mr. Williams has summarized the various features in his Observations and Conclusions beginning on page 18, and the reader is referred to that part of

the report for a concept of the work in abbreviated form. Anyone interested in construction of this type can, of course, get a better understanding of the project through reading the entire report. I hope that at least one project with a vibrated base will be included in the program of construction for the coming year, and that there will be a supplementary blade-spread course of some type in order that the merits of such a combination can be determined.

Respectfully submitted,



L. E. Gregg
Assistant Director of Research

LEG:ddc
Copies to: Research Committee
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Commonwealth of Kentucky
Department of Highways

Report No. 1

on

VIBRATORY COMPACTION OF A MACADAM BASE

by

Ellis G. Williams
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December, 1953

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INTRODUCTION

Macadam, either dry or water-bound, is probably the most widely used type of base for flexible pavement construction. Until recently, the traditional water-bound macadam construction has been done in successive courses each approximately as thick as the nominal size of the largest stone represented in the course. This method produces satisfactory results but it is relatively slow since multiple courses are normally required to attain the necessary base depth.

Methods and equipment have recently been developed to permit construction of macadam bases in single courses of relatively great depth. Several years ago a vibratory roller was developed in Denmark to permit compaction of thicker single courses. This roller was of the three-wheel tandem type with the middle wheel containing a vibrating device. The machine was introduced in this country in 1946 (1), and while it apparently produced reasonably satisfactory results, it has been abandoned, at least temporarily. In 1946, the International Vibration Company developed a vibrating tamper. This self-propelled machine consisted essentially of six 20 by 25-in. shoes, each containing a vibrating unit. More recently a similar machine has been developed by Jackson Vibrators, Inc.

Experimental work in Ohio (1)(2)(3) has included construction of comparative bases (8-in. compacted depth) using both vibratory compaction in one course and conventional roller compaction in two courses. The results of this work indicate relatively little difference

in composition of these bases or in the initial bearing strength, as measured by plate bearing tests on the compacted bases (3). Additional bearing tests were performed after one year and these tests, made on the bituminous surface, showed increases in strength for bases constructed by each method. After one year, the strength of the single-course vibrated base was appreciably higher than that of the two-course water-bound base. These findings, together with the economic advantage of one-course construction, resulted in vibratory compaction being added to the Ohio specification as an alternate method of macadam base construction. The Civil Aeronautics Authority, U.S. Army, U.S. Air Force, and many states have adopted, or are using experimentally, this method for macadam base construction.

During the past year, the first vibratory compaction project in Kentucky was carried out on a 2-mile section of U.S. 62 in Anderson County, as a part of the reconstruction of the Lawrenceburg-Versailles Road. The project started in Lawrenceburg and extended to a point near the Tyrone Bridge over the Kentucky River (See Fig. 1). Construction was carried out by contract during the period August to November.

The newly constructed subgrade with a traffic-bound surface had been exposed to local traffic for one year prior to construction of this project. The pavement consisted of 8 in. of macadam base constructed in one course; 3 in. Class I bituminous base; 1-1/2 in. Class I, Type B bituminous binder; and 1-1/4 in. of Class I, Type B bituminous surface (See Fig. 2).

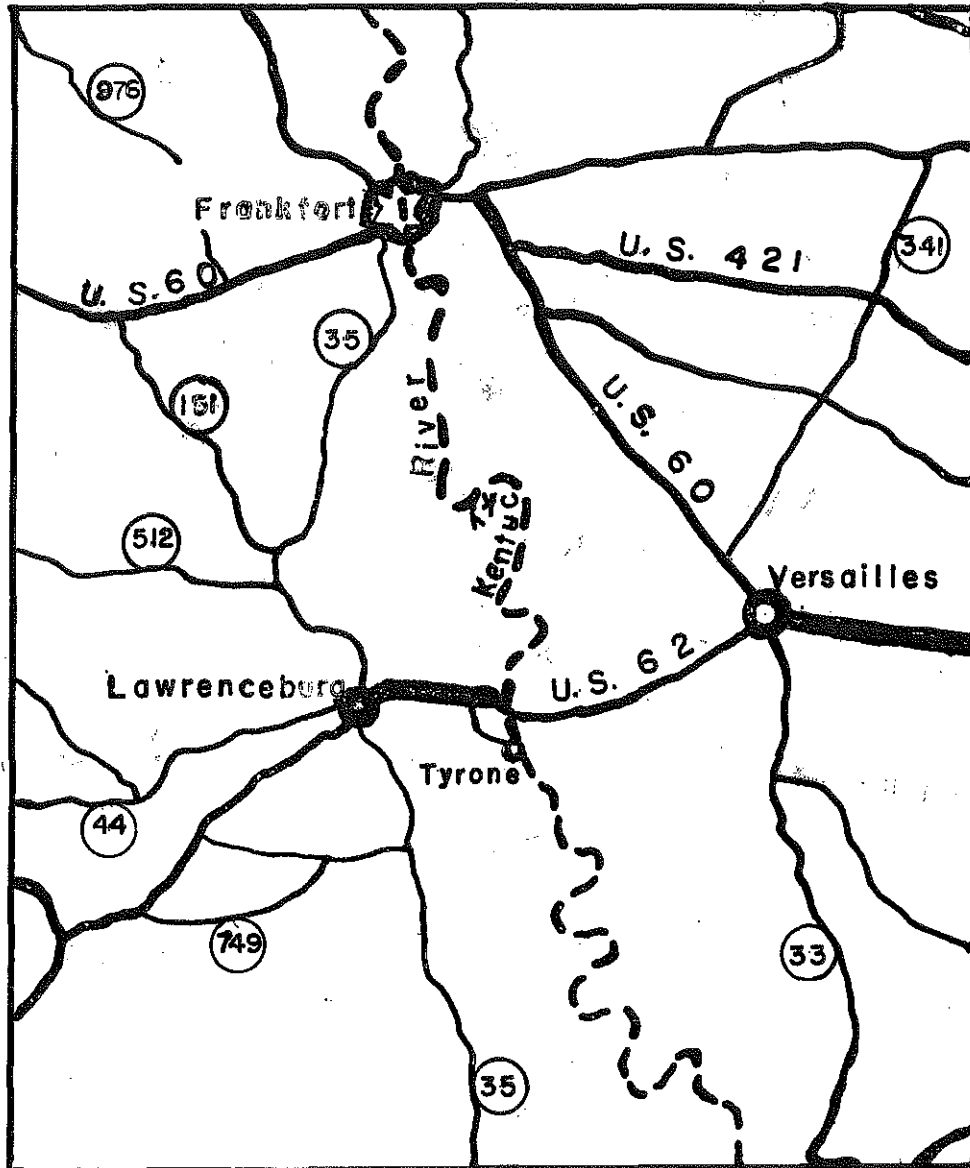


Fig. 1 - Sketch map showing the general area of the vibrated macadam base project. Specific location of the project is indicated by the heavy solid line on U.S. 62, between Lawrenceburg and the Kentucky River. Crushed limestone was produced by the Kentucky Stone Company plant near Tyrone.

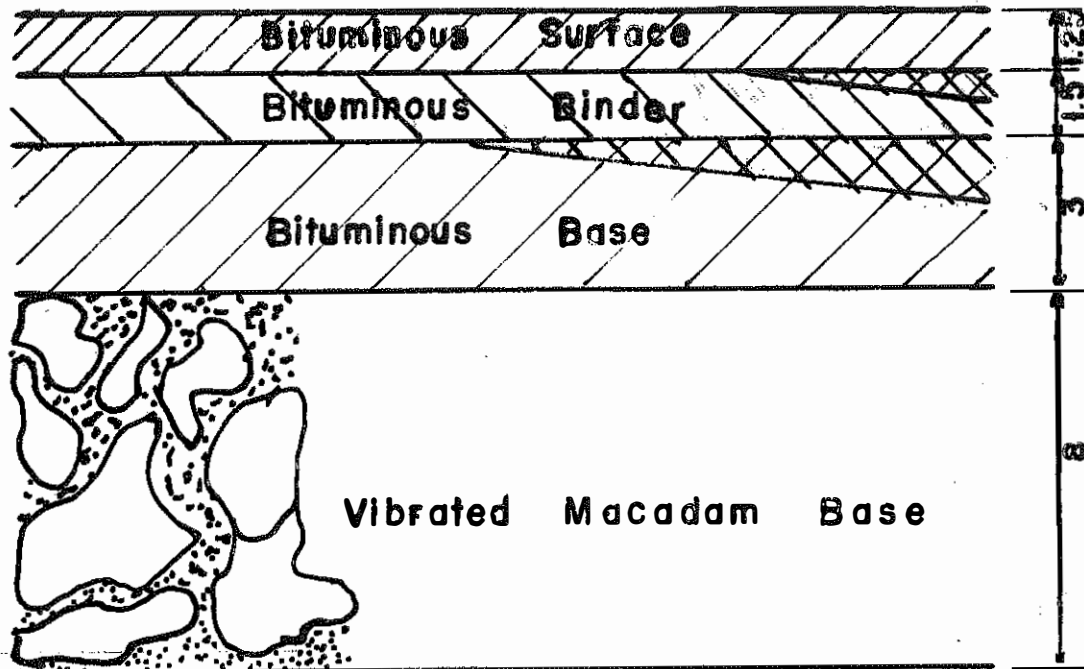


Fig. 2 - The pavement section used on the project and illustrated above, was underlain by approximately 1.5 in. of traffic-bound limestone and at some locations by an insulation course. Courses shown are the vibrated macadam base which was constructed in one course; Class I, Type B bituminous binder; and Class I, Type B bituminous surface. Wedge-shaped sections of bituminous mix shown in the sketch represent the blade-spread leveling materials which were employed intermittently and as required to reduce irregularities in the underlying course.

Aggregate used in all courses consisted entirely of crushed limestone. The coarse or key stone grading was designated size No. 1-A under Special Specification No. 57. Nominal size for this material is 1-1/2 to 3-1/2 in., with 100 percent passing a 4-in. sieve, and not more than 10 percent passing a 1-1/2-in. sieve. This grading differs from the standard No. 1 stone in that it contains higher percentages of coarse sizes; in other words, No. 1-A approaches a one-size aggregate.

Several thousand tons of stone intended for use in this project had been stockpiled prior to the start of construction. This stone was deficient in coarse sizes and also greatly exceeded specification limits in the fine sizes. As a result, a large portion of this material was rejected for base construction. Production was revised, and the resulting stone met grading requirements. Even then the percentage of flat and elongated particles, though not determined, appeared to be high, especially in the 3-1/2 to 4 in. fractions. These particles were of doubtful value to the base. Had the stone crushed to more cubical shapes, the coarse fraction would have been more effective.

Screenings graded to meet Special Specification No. 57, designation No. 10-A, were used for choke stone. This stone, which has a nominal size of 0 to 1/2 in., differs from the standard No. 10 stone in that it has better size control and a higher percentage of the fine sizes are required. The stone produced for this project met grading requirements but tended toward flat particle shapes.

The principle objectives of investigations on the project were: to determine the feasibility of one course construction of macadam bases by vibratory compaction, and to establish construction methods which produce desirable qualities in the base plus a maximum smoothness in the surface.

EQUIPMENT

Coarse stone was placed with a spreader box constructed by the contractor and illustrated in Fig. 3. This box was mounted on a dozer U-frame assembly and pushed by a crawler tractor which operated on the stone that had been spread. The front of the box was supported by two wheels mounted on screw jacks, which permitted adjustment in depth and, to some extent, in section. Adjustable side gates (See Fig. 4), lowered to the subgrade, prevented feathering of the edges as the course was spread. A wooden straight edge (approximately 6 ft. long and 10 in. high) attached to the lower edge of the side gate at the center line further improved the vertical character of base stone at this point, and insured a clean working surface for placement of stone in the adjoining lane. A disc attachment, also shown in Fig. 4, forced the earth against the side gate, insuring firm contact between base stone and the abutting shoulder material. This, of course, retarded lateral movement of stone during later compaction operations. The equipment is well adapted to handling large quantities of stone and performed in a satisfactory manner.

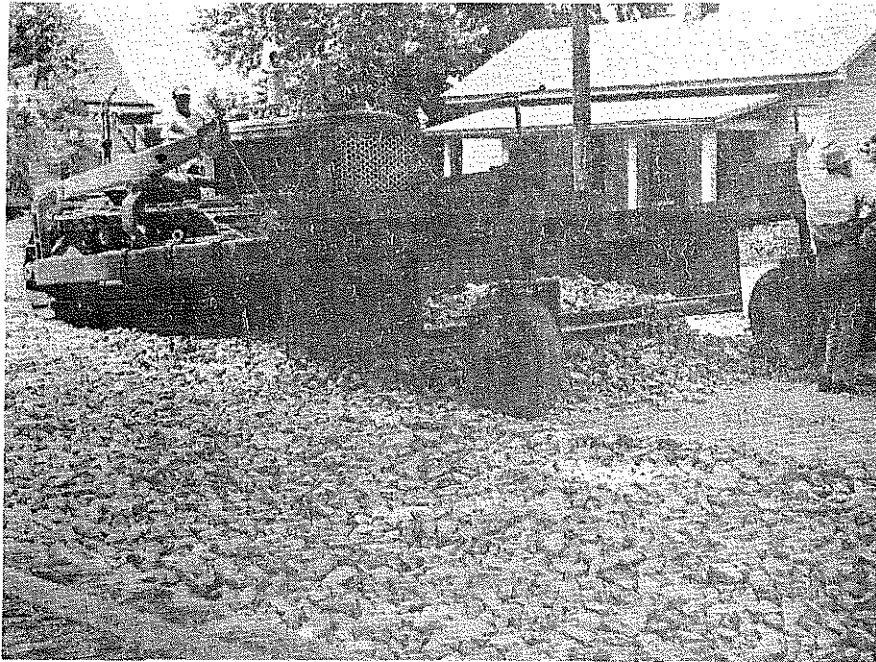


Fig. 3 - Spreader box used for spreading coarse stone. The rear of the box is supported by the dozer U-frame. Screw jacks on front wheels permit adjustments in depth of stone spread. The crawler tractor, furnishing propulsion, operates on the stone being spread.

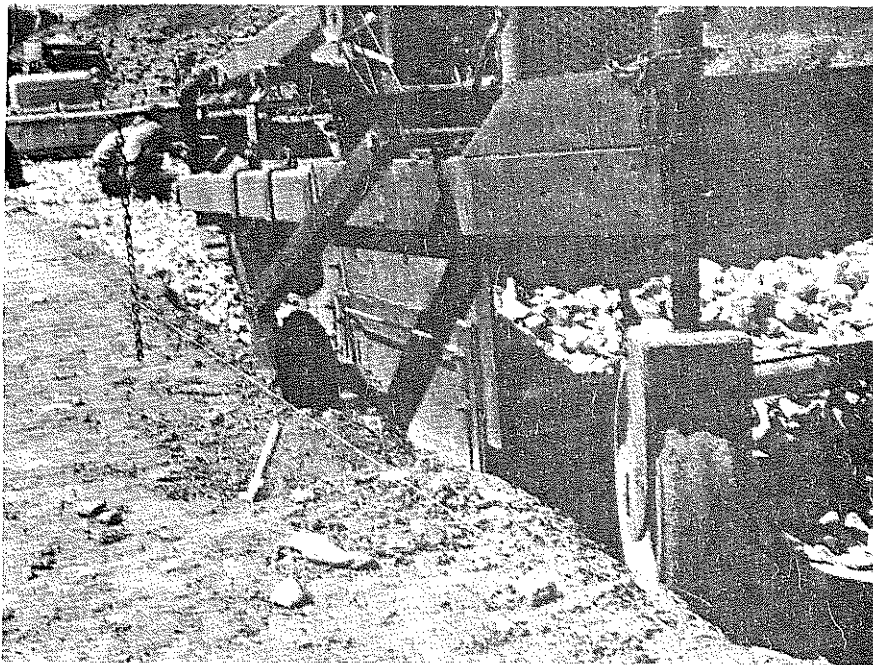


Fig. 4 - Spreader box with adjustable side gate lowered to produce a clean edge on the base course. The disc attachment on the arm pulls soil from the abutting shoulder material against the side gate and provides a firm contact between the soil and base stone.

Screenings were placed with tailgate spreader boxes. These devices encourage erratic application rates, and the distance through which the screenings fall promotes segregation of coarse particles. Towed spreaders such as the "Buckeye" box are much better suited to this purpose.

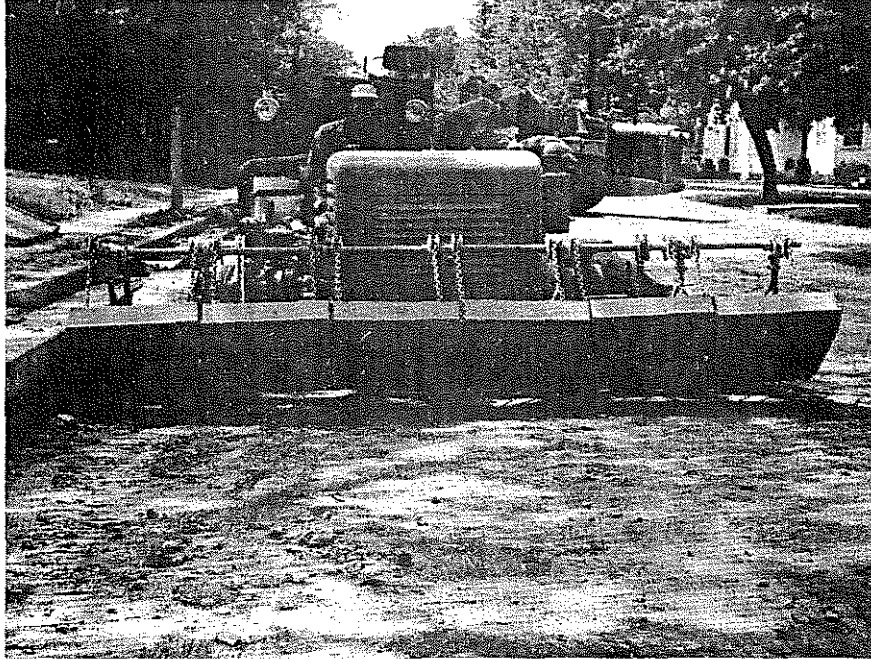
A Model 1952 Vibro-Tamper was used for all vibratory compaction, keying, and choking (See Fig. ³5). The tamping mechanism consisted of six 20 by 25-in. shoes (individual contact area - 240 sq. in.) each containing a vibrating unit delivering 2200 vibrations per minute. Each shoe weighed 450 lbs. and had a 1/4-in. vertical lift. The machine has six forward speeds ranging from 20 ft. per min. to 150 ft. per min., and two speeds in reverse. The manufacturer recommends tamping during forward movement only; however, successful use of the machine in reverse - after an initial pass - has been reported.

A 10-ton tandem roller was used in compacting and smoothing the insulation course and in construction of the bituminous courses. Two 10-ton three-wheel rollers, equipped with brooms, were used during the last step or water-binding of the macadam base and later in construction of bituminous courses.

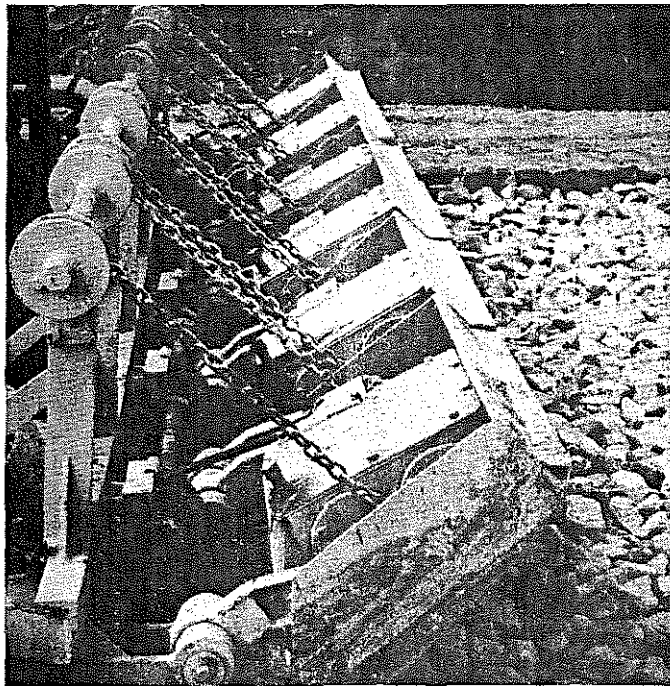
Two sprinkler trucks, each having 1000-gal. capacity, were used for wetting the base during water-binding operations.

A Barber-Greene paver and finisher was used for placing all bituminous courses with the exception of leveling material tailgated onto the pavement and blade-spread by a grader equipped with an edger.

Bituminous mixtures were prepared in a Barber-Greene continuous type mixing plant.



(a)



(b)

Fig. 5 - (a) Frontal view of the Vibro-Tamper. The vibrating shoes are shown in the raised or traveling position. Note the curved bottom plate on each shoe which reduces contact area and permits tamper to operate over minor irregularities. (b) Top view of the shoes. Vibrating mechanisms are enclosed in the rectangular containers mounted on each shoe. Each vibrator is independently operated by the drive shaft.

MACADAM BASE CONSTRUCTION

Construction was carried out with the road closed to all but local traffic requiring access to adjacent property. With few exceptions, all traffic was kept off the base until the final step of water-binding was completed.

As an initial operation the subgrade was dressed with a motor grader to correct deficiencies in section. Shouldering material was placed at the edges to permit its use as earth forms during construction of the base.

An insulation course of No. ¹⁰~~35~~ stone was applied as needed prior to placement of the base. Only those areas where the traffic-bound course had been removed by traffic or grader action were insulated. This course was incidental to construction as a whole.

On August 17, the base was started within the corporate limits of Lawrenceburg, and work proceeded eastward. From the starting point to the city limits - a distance of approximately 750 ft. - two parking lanes were added to the normal 22 ft. width. Within this section there were curbs and gutters and a major street intersection as well. In addition, there were numerous obstructions (manholes and water cutoffs), protruding from the subgrade. Considerable difficulty was experienced in base construction throughout this area due to both the obstructions and lack of experience with the equipment.

Spreading Coarse Stone. All stone was placed in one-lane widths with the spreader box previously described. Shaping of the subgrade established the required crown, permitting spreading at uniform depths.

Loose stone to a depth of approximately 10-1/2 in. was required to produce the desired 8-in. compacted base.

In the early stages of construction attempts were made to smooth freshly laid stone by use of a motor grader and thus largely eliminate hand picking. This procedure was entirely impractical and soon abandoned. Areas partially compacted by tractor treads or grader wheels received additional stone during the blading operation. This combination of influences produced high spots in the compacted base.

The most satisfactory results were obtained when mechanical manipulation was eliminated and the stone was left essentially as deposited by the spreader box - all adjustments for depth and section being made on the box. Hand picking immediately followed spreading to make necessary adjustments in the stone. Had experienced pickers been available, the operation possibly would have been successful. However, with the inexperienced pickers, results were not satisfactory.

The Vibro-Tamper was used to assist the pickers in locating high and low spots. Through operation of the tamper at top speed (150 ft. per min.) to smooth and lightly compact the base stone, high and low spots showed up more prominently and hand picking was facilitated (See Figs. 6 and 7). Compactive effort was insufficient to produce keying and no difficulty was experienced in removing stone. As the job progressed it became standard procedure for the tamper to perform this function. Maximum smoothness was attained by this method and it tended to minimize the effects of inexperienced personnel, disturbance of stone under traffic, and limitations of the stone-spreading methods.

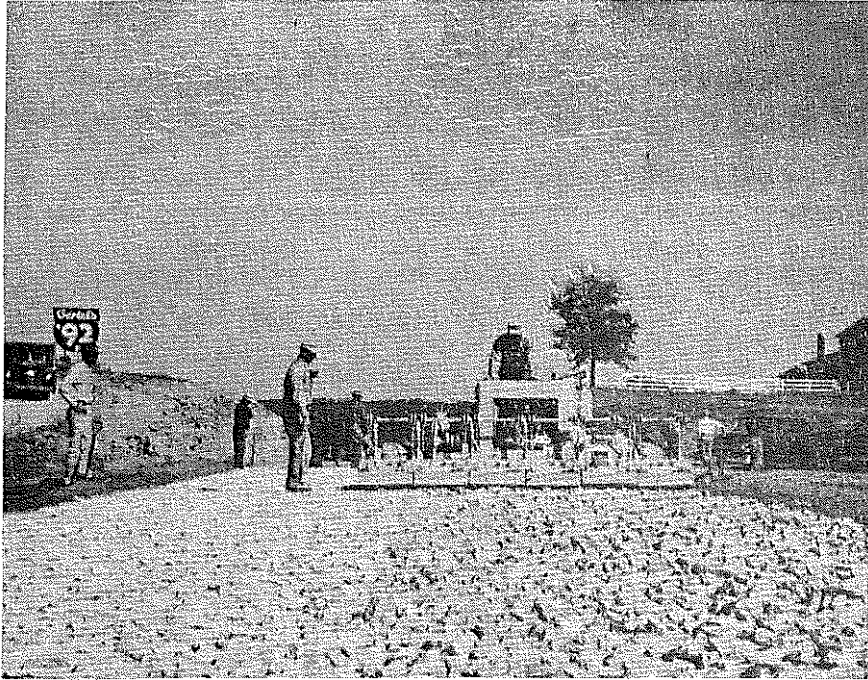


Fig. 6^A - Smoothing pass of the tamper. Left lane has been lightly tamped. Note difference in appearance of the two lanes. Vibrator was operated in essentially the same manner but at a much slower rate for the keying of the stone after the base had been hand picked for elimination of high and low spots. Forward rate in the smoothing pass was 150 ft. per min, while in the keying pass it was 20 ft. per min.

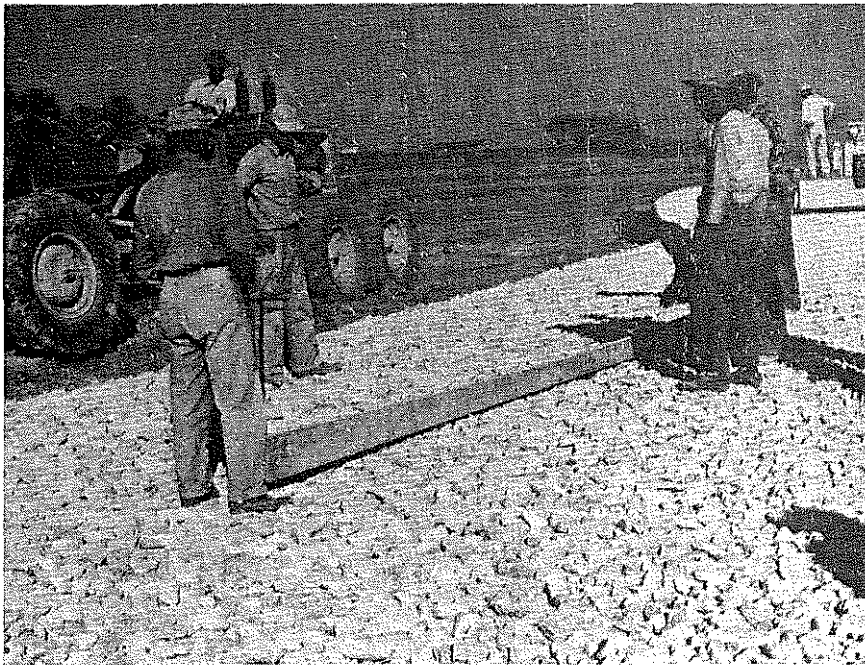


Fig. 7^B - Use of templet to locate high and low spots in base stone. The tamper has made a smoothing pass, and hand picking to correct the section will be completed prior to the keying pass of the tamper.

Stone was spread in one lane for a relatively short distance (usually 500 ft. or less) before the adjacent lane was brought abreast. The length of section was somewhat dependent upon the rate at which stone could be delivered. Best results were achieved when the full-width of stone was placed, tamped initially, picked, and checked with the templet before keying of the coarse stone, placement of screenings, and compaction with slow passes of the vibrator were started.

Keying. The special provision under which this base was constructed provided that sufficient keying should be attained with the vibrating tamper to permit rolling with a three-wheel roller without displacement of stone. This procedure was followed in the early stages and then abandoned for the following reasons:

Compaction by the tamper produced tighter surface keying than could be attained by combined tamping and rolling. Stone particles firmly set in position by tamping were displaced by the roller which tended to orient surface particles so that one face lay in the surface plane. On the other hand, the tamper tended to drive surface particles into position so that some point was in the surface plane, but it showed little tendency to orient particle faces. The exception to this occurred in the case of large flat particles which were usually positioned with a face in the surface plane regardless of the compactive method used.

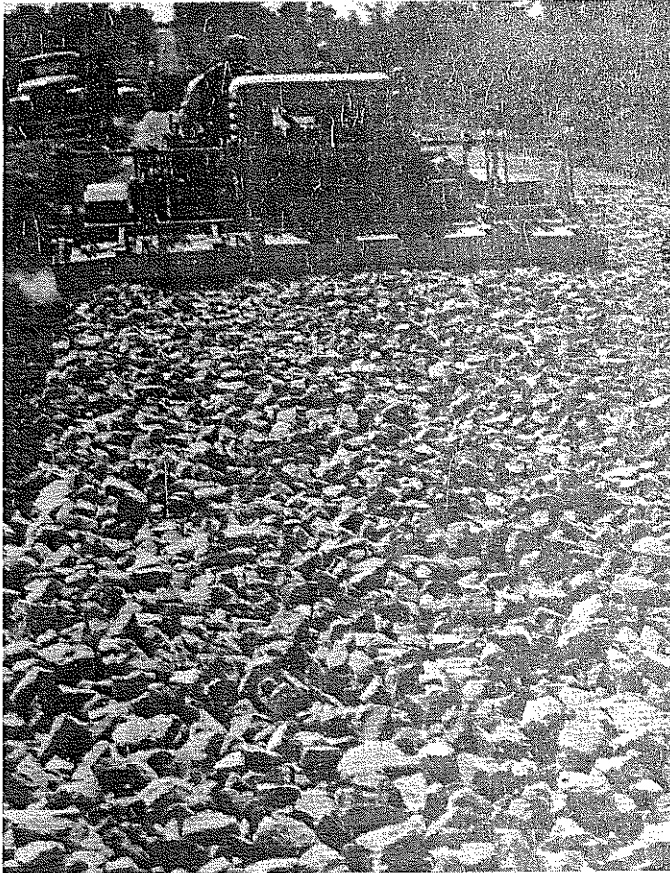
Since tamping often left points at the surface, subsequent rolling caused crushing which produced undesirable intermediate and fine sizes of aggregate. This crushed material tended to block surface voids, preventing proper penetration of choke stone. Degradation was particularly noticeable where large flat particles were present. These particles were a hindrance to proper compaction regardless of the method used.

Rolling appeared to smooth out some irregularities left by tamping. This, however, applied to early stages of construction where the tamper was not used prior to hand picking. The roller was not used after the smoothing technique was adopted.

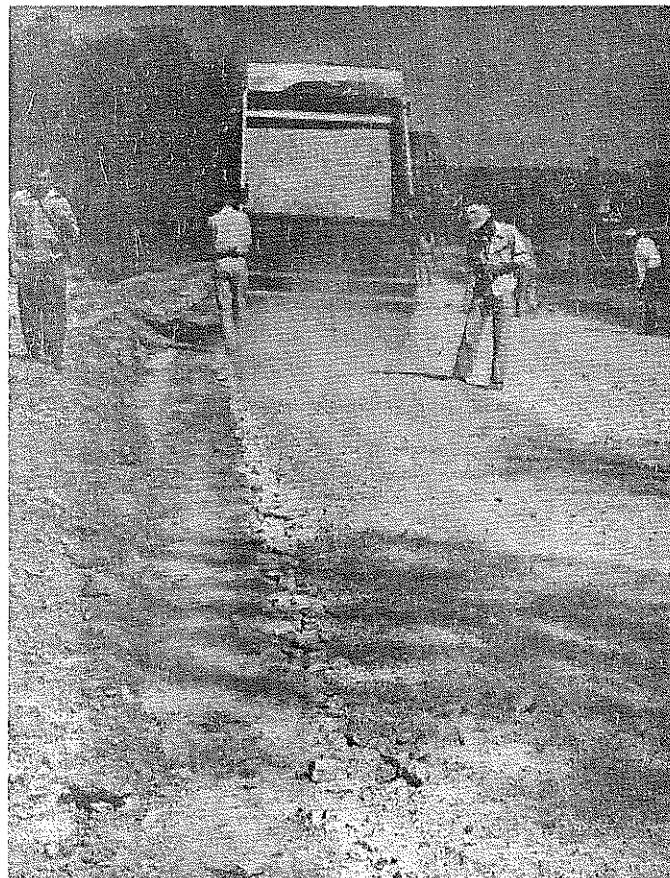
The roller was also used to a limited extent for compacting the edges prior to the use of the tamper for keying the coarse stone. In this operation the roller was operated for one coverage (one pass in each direction) with the outside wheel overlapping and compacting the earth form. Lateral resistance was improved slightly, but the objectionable influence of the roller already noted, plus its disturbing effect on the lightly compacted stone, made any use of the roller at this stage undesirable.

For the majority and the most satisfactory portion of the project, keying was accomplished with the tamper alone. After the work of smoothing, picking, and checking the section were completed, the tamper was operated at its lowest speed (20 ft. per min.) for one pass over the entire base. Additional passes of the tamper during keying appeared to produce no advantage as to either density or smoothness, so on the majority of the project keying was limited to the single pass.

Irregularities caused by variations in depth of stone or incorrect section were not eliminated by the tamping operation. The reason for this is illustrated clearly in Fig. 8. There is a slight tendency on the part of the vibrator to smooth those spots where a shoe overlaps both high and low areas. However, the machine can not



6
Fig. 8 - Vibrator operating over roughly-placed coarse stone. Although the stones shift positions during the keying process, the extent to which irregularities can be removed is dependent upon the position taken by the stone when it becomes firmly set and, therefore, upon the effectiveness of spreading and picking.



7
Fig. 9 - Spreading screenings from a tailgate spreader box. Uniformity of application at this point is above average for the job. Note lack of screenings near the edge.

key the stone and move it about to new positions at the same time. If the base course is to have a smooth surface, it must be attained by correct spreading and picking of base stone prior to the keying pass of the tamper. This pass keys the stone firmly and makes corrective measures very difficult. Damage to the base, as a whole, may result from attempts to remove stone after keying. Therefore, irregularities existing after keying should be corrected in subsequent courses rather than in the macadam base.

Placement of Screenings. All screenings were applied by trucks equipped with tailgate spreader boxes, as shown in Fig. 9. This method produced erratic results through obviously variable rates of application.

Shoveling and brooming of screenings was often required to produce uniform coverage. This operation, especially brooming, tended to produce mats where the screenings, under vibration, compacted on the surface instead of settling into the voids. Matting, to a lesser extent, resulted from passage of any vehicle prior to vibration of the screenings.

Choking was accomplished in three applications of screenings. The first application represented approximately 50 percent of the total stone required, and this was vibrated into the voids of the coarse stone with one pass of the vibrator in each lane. Approximately 25 percent of the total was spread and vibrated in the second application. The remaining portion of stone screenings was placed by the usual water-bound method involving dry brooming and rolling followed by wetting, brooming, and rolling until a slurry filled all surface voids.

Operation of the vibrator in the placement of screenings from the first application is shown in Fig. ⁸10. The entire width was covered and tamping was started at the slow forward rate (20 ft. per sec.). A single pass was used to vibrate choke stone into the voids. Effects of vibration on screenings were visually evident as far as 20 ft. in front of the tamper. These effects can be observed in Fig. 10 as openings in the mat of screenings. For the purpose of comparison, Fig. ⁹11 shows the same area after passage of the vibrator. Virtually all screenings infiltrated the coarse stone. Small matted areas, usually consisting of coarser sizes of screenings, were often left on the surface.

The second application of screenings was made in the same manner as the first, and immediately after passage of the tamper over the first application. Following this, the base was vibrated again with the tamper operating at the same speed = 20 ft. per min. (See Fig. ¹⁰12). Most of these screenings settled into voids; however, a larger percentage of the surface remained covered with screenings after this passage of the tamper than was the case when the first application was vibrated. This condition, which is illustrated in Fig. ¹¹13, implies either overfilling or blocking of the voids. Stone remaining on the surface was sometimes broomed into open spots, but it is doubtful that this action produced any beneficial results since mechanical brooming and rolling was to follow.

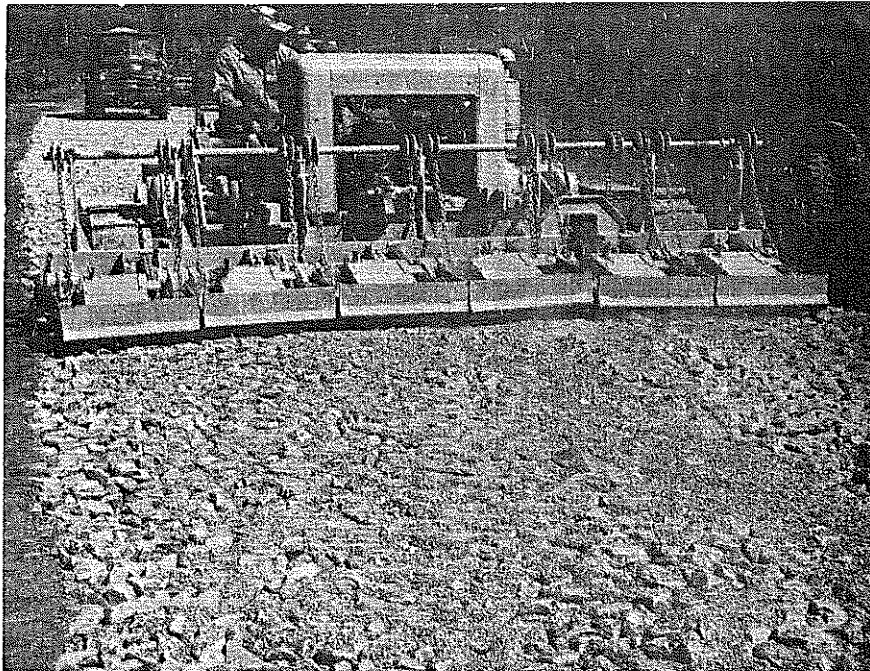
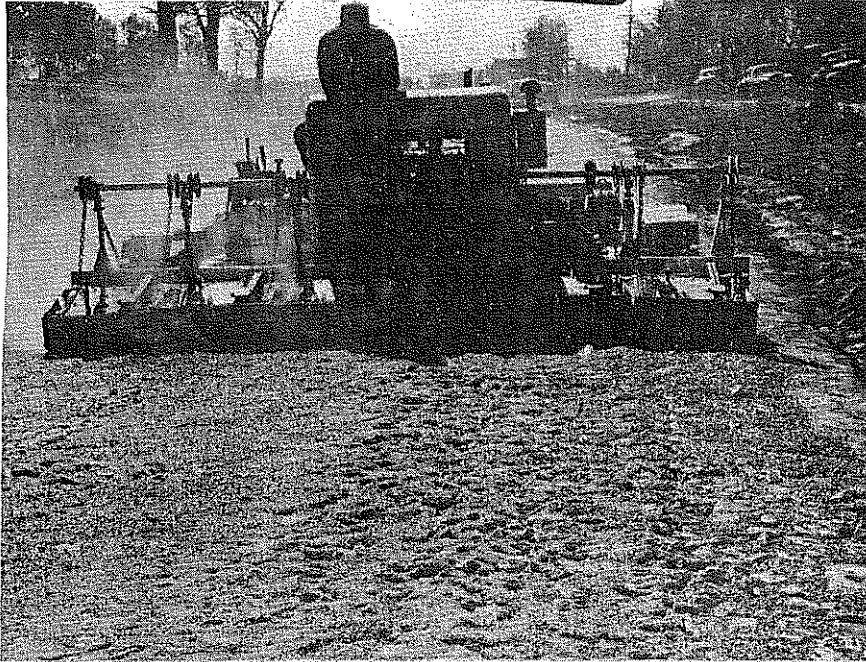


Fig. 10 - Vibrating the first application of screenings (50 percent of the total quantity) into the voids of the coarse aggregate. Openings in stone mat indicate effectiveness of vibration several feet in front of vibrator. Tamper is operating at 20 ft. per sec.



Fig. 11 - Location shown in Fig. 10 after passage of the tamper. Most of the screenings have infiltrated the coarse base stone. Note spots still covered with coarse screenings. Some difficulty was encountered where coarse screenings blocked voids and prevented complete choking of the coarse stone, particularly in the second application of screenings that followed.



¹⁰
Fig. 12 - Vibrating of the second application of screenings (25 percent of the total quantity).



¹¹
Fig. 13 - Location shown in Fig. 12 after passage of the vibrator over second application of screenings.

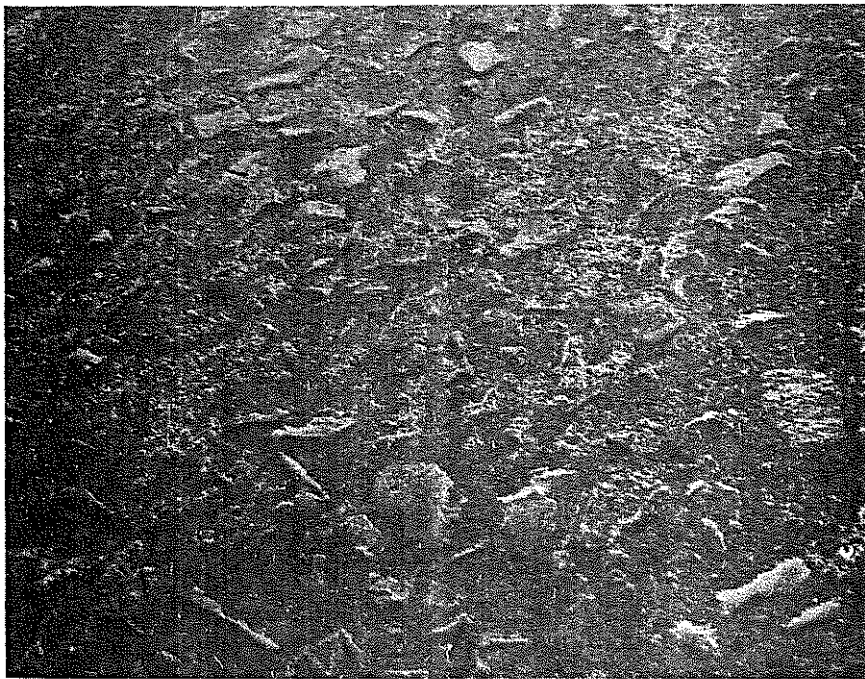
Normal use of the tamper during vibration of both the above applications was a single pass at the slowest forward rate. Other speeds were tried but were judged to be much less effective on the basis of material left on the surface. Additional passes were also attempted but this additional effort appeared to produce very little advantage. All passes of the tamper were assumed to improve keying of coarse stone as well as filling of voids; however, no measurements were made to establish this. Excessive tamping during choking has been reported (1) detrimental, in that after screenings are vibrated to the bottom of the base course additional vibration may produce upward migration of coarse stone and consequent reduction of interlock of coarse stone obtained by the keying pass of the tamper. No evidence of migration was noted on this project.

The third and final application of screenings was made immediately following tamping of the second application. This portion of construction followed standard procedures used with water-bound macadam (See Fig. ¹²14). Dry rolling and brooming distributed choke stone and worked it into the surface voids. Thorough wetting was accomplished in the usual manner, after which wet rolling and brooming continued until the surface was dense and uniformly compacted.

Wherever possible, all traffic was kept off the base actually being constructed until choking and water-binding was completed. However, local traffic was permitted to use all sections immediately



¹²
Fig. 14 - General view of water bonding operations.
Dry brooming and rolling of the section has just been completed and sprinkling is starting. In the background the tamper is vibrating screenings on the next section.



¹³
Fig. 15 - Typical appearance of completed base after it had been subjected to local and construction traffic for several days.

following construction. Generally, the surface remained tightly bound as shown in Fig. 15¹³, yet, in spots where screenings were exceptionally coarse, some raveling occurred (See Fig. 16¹⁴). This condition was never serious and no more severe than in bases constructed by standard methods.

BITUMINOUS PAVING

The macadam base was overlain by approximately 5-3/4 in. of bituminous pavement constructed in three courses: a 3-in base, a 1-1/2-in. binder, and a 1-1/4-in. surface. Limited additional thickness in the form of blade-spread binder and surface leveling courses or wedges, was added at some locations in an attempt to produce a smooth riding surface.

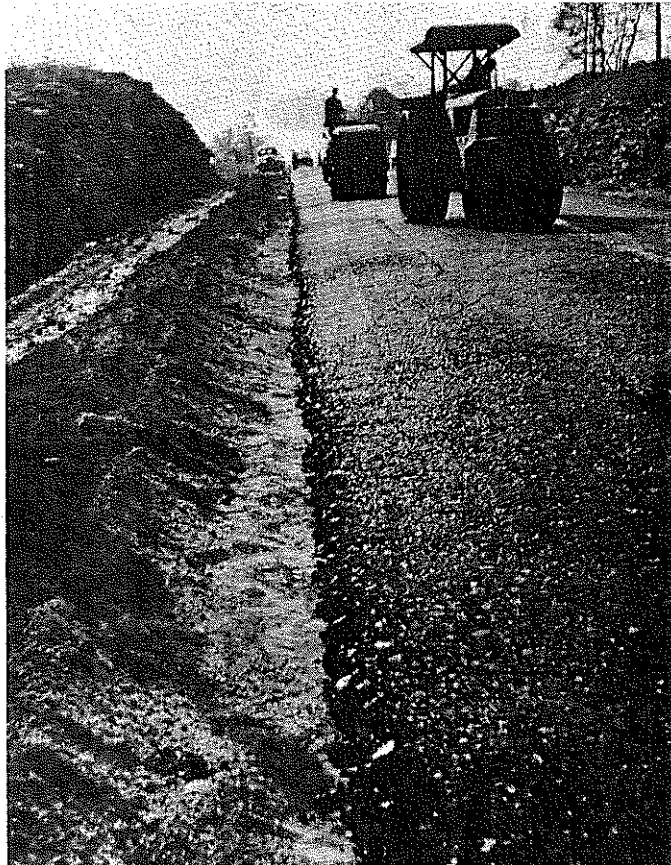
Base Course. The Class I bituminous base mixture was placed directly on the macadam base.

Prior to paving, the macadam was swept clean of loose stone by a rotary broom supplemented by hand brooming when necessary. No prime was used on the macadam base. This omission had little effect on base construction except near the edges where there was considerable lateral creep, as illustrated in Fig. 17¹⁵. Lateral movement, being largely dependent upon texture of the macadam base, was irregular and waviness along the edges resulted. A prime coat over the outer 4 ft. of the macadam would have restricted much of this movement.

Grading specifications for Class I base were met in the mixture used; however, the quantity of stone in the coarse sizes often appeared



16
Fig. 16 - Localized raveling probably caused by lack of fines in the screenings. More severe cases were noted elsewhere on the road, but the condition was never severe nor worse than that of an average water-bound base constructed entirely by conventional methods.



15
Fig. 17 - Compacted bituminous base placed over the unprimed macadam. Note irregular edge caused by lateral movement during rolling.

to be near the maximum. These sizes act principally as bulking material and add very little to the stability of the mixture. While the texture of the base was generally satisfactory (See Fig. 18), there was a distinct tendency on the part of coarse particles to segregate and produce open-textured spots in the pavement. During rolling these spots consolidated more than well-graded surrounding material, producing an irregular surface. If the segregated area was small enough to be at least partially bridged by the roller, sufficient compaction was not obtained. At such spots consolidation may occur under traffic loadings. Elimination of sizes larger than 1-1/2 in. in base mixtures would reduce the possibility for development of this condition.

It was hoped that irregularities in the macadam base could be largely eliminated in the bituminous base course. While some of the larger irregularities were reduced, attempts to achieve a uniform section were at best only partially successful, and roughness in the macadam course carried through the bituminous base.

Blade-Spread Leveling. In an attempt to overcome the tendency to transmit original irregularities from one course to another in the construction of bituminous pavement, leveling material was blade spread over the base and binder courses for limited distances. All this type work was confined to portions of pavement in the first mile eastward from Lawrenceburg. Binder mix was used in leveling the base, and surface mix was used in leveling the binder course.

Initial spreading was accomplished by tailgating the mixture as uniformly as possible on the areas to be leveled. An entire truck load



Fig. 18 - Typical texture of the bituminous base immediately after rolling. In general, the surface of this course was satisfactory, although segregation of coarse aggregate occurred at some points.

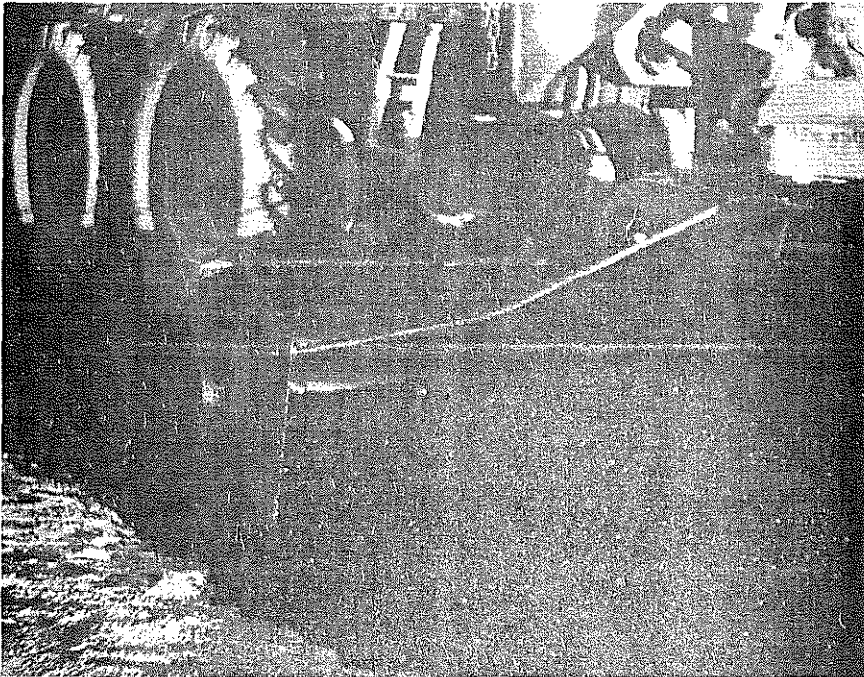


Fig. 19 - Blade-spreading hot-mix leveling material with a grader. The mix handled well and did not chill enough to pull under the blade.

(approximately 7 tons) could be spread at one time. Laying out was done with a patrol grader in order to gain the advantage of a wheel base longer than that of a conventional paver. The blade was equipped with an edger attachment, as shown in Fig. ¹²19. The operator had previous experience in blade-spreading hot mixes while placing the experimental resurfacing section on U.S. 68 north of Millersburg (4). As on the previous work, the operator had no difficulty producing an improved section.

Rolling followed the spreading as closely as possible so that the effects of cooling would be reduced (See Fig. ¹³20). In general, the compacted mixture appeared to be quite dense and compared very favorably with machine-spread mixtures so far as surface texture was concerned (See Fig. ¹⁴21).

Where irregularities still existed in the finished binder course, additional leveling with blade-spread material was done prior to the laying of Class I surface. The same technique was employed in placing and compacting material, and only the mixture was changed. No difficulties were encountered in working this material.

Binder and Surface Courses. Class I, Type B binder and surface courses were spread and compacted in the usual manner. These mixtures were composed entirely of crushed limestone and contained a PAC-5 (85-100 penetration) asphalt. Nothing unusual existed either in the mixtures or in methods of construction.

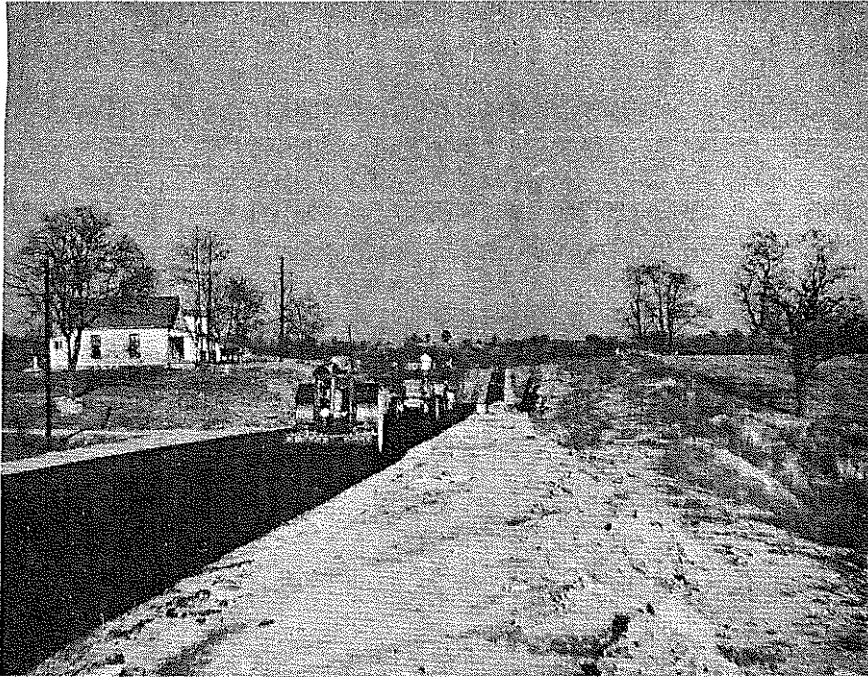


Fig. 20¹² - Sequence of blade-spreading operations. Rolling followed spreading as closely as possible to minimize effects of chilling the mix.



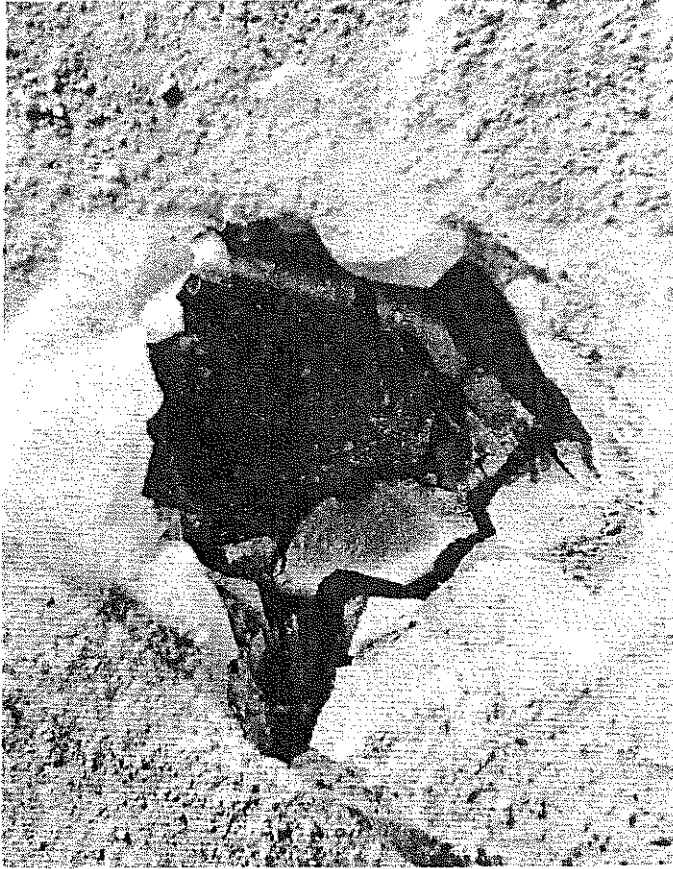
Fig. 21 - Typical surface texture of blade-spread Class I binder leveling material.

FIELD AND LABORATORY TESTS

Tests were directed mainly toward determination of compacted density of the macadam base and establishing sections for study of changes in surface characteristics over a period of time. Grading of aggregates was tested and controlled by the Division of Tests.

Density tests were made by personnel from both the Research and the Testing Laboratory. Tests were made by the Testing Laboratory at six locations and by the Research Laboratory at two. The sand-density method was used in all cases. This method consists of carefully removing compacted base stone from a roughly cylindrical section of the base (See Fig. ²²22), and measuring the bulk volume as well as the weight of material removed. Determination of the volume is based on the amount of calibrated sand required to refill the hole (See Fig. ²³23).

The degree of density or percentage of maximum density (percentage of solid volume) was also determined. Density data, together with percentages of coarse aggregate and screenings, for all sample locations are contained in Table 1. The average percentage of maximum density of 82.4 in the macadam base is within the density range of compacted aggregates in a Class I base mixture as is the average unit weight of 139.1 lb. per cu. ft. Comparisons between these mixtures are hardly valid, and they are made only because at present no data are available on conventional water-bound macadam containing similar stone.



²⁰
Fig. 22 - A roughly cylindrical section of completed macadam base excavated for sand density test. Coarse aggregate was tightly keyed and very difficult to remove. In this location voids were well filled except under the large flat stone near the bottom of the hole.

²¹
Fig. 23 - Test hole filled with calibrated sand. The quantity of sand required to fill the irregular hole was measured to determine the bulk volume of the stone removed. The weight-volume relationship, of course, represents density (or more correctly, unit weight) of the compacted base.

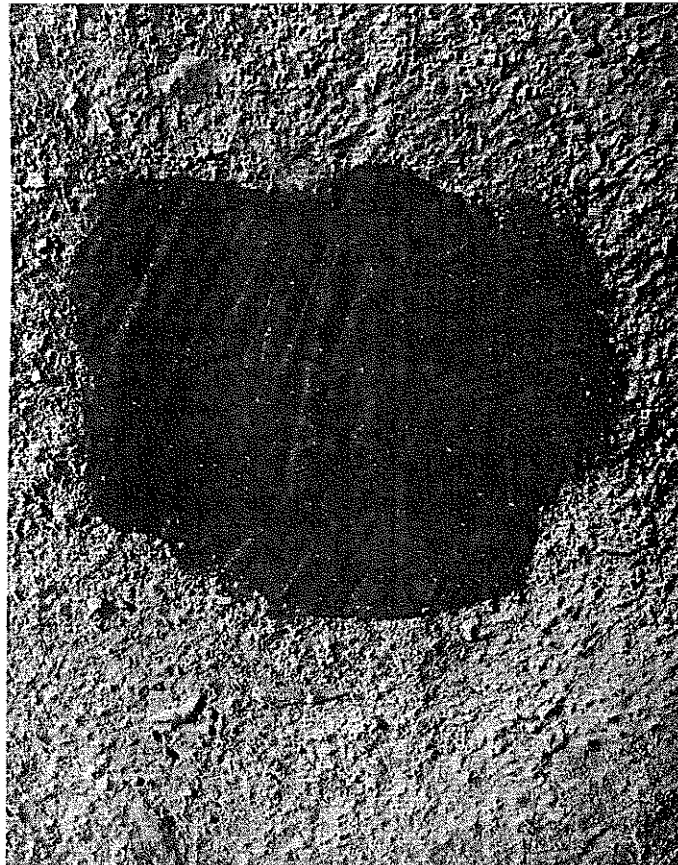


Table 1. Data Pertaining to Vibrated Macadam Base

Test Hole	Location Sta.	Thickness Base in.	Unit Wt. lb. per cu.ft.	Percentage of Screenings	Percentage of Max. Den.
1	29 + 50	12.1	127.3		
		4 in. of stone at bottom not part of vibrated base. Many voids unfilled, apparently due to clogging of upper voids by coarse particles. Coarse aggregate not well keyed.			
2	33 + 50		130.0	23.7	77.0
		Coarse aggregate fairly well keyed. Some unfilled voids evident, apparently caused by clogging due to coarse particles in screenings.			
3	60 + 00	7.5	139.7	33.6	82.7
		Coarse aggregate well keyed and voids filled.			
4	80 + 14	8.8	135.4	27.8	80.3
		Coarse aggregate not well keyed and unfilled voids numerous.			
5	105 + 21	8.8	138.6	29.0	82.1
		Coarse aggregate well keyed. Some unfilled voids observed.			
6	120 + 50	8.5	137.4	34.3	81.4
		Test made while base was still wet and keying not evident. Voids appeared to be filled.			
7	120 + 00		140.3	33.9	83.2
		Tight key - few unfilled voids.			
8	124 + 00		142.9	30.6	84.7
		Tight key - some large voids unfilled.			
Avg. Values			139.1	31.5	82.4

Tests 1 to 6 made by Division of Tests; tests 7 and 8 made by Research Laboratory.

Note: Tests No. 1 and 2 eliminated from averages. Represent early construction prior to use of 1A stone and therefore do not reflect condition of that portion of base being studied.

The average percentage of screenings (31.5* percent worked into the voids by the vibratory process was just greater than the usual amount (approximately 30* percent) in estimating quantities for water-bound macadam. Those sample locations that had few or no unfilled voids contained an average of 33.9 percent screenings. This latter value probably is near an optimum condition.

Small unfilled voids in the keystone were noted at several locations. These open voids occurred where flat particles of keystone blocked passage of screenings or more frequently where coarse screenings blocked the voids and prevented further infiltration of fine stone. This latter condition indicates the need of a revised grading for screenings in order to reduce the coarser sizes, especially material coarser than a 3/8-in. sieve.

At two points on the project - between Sta. 84 + 00 and Sta. 94 + 00, and between Sta. 120 + 50 and Sta. 126 + 00 - cross sections of each course were made at 50-ft. intervals to establish initial conditions from which changes in sections may be judged. Later measurements of a similar nature will be made to determine changes in sections due to settlement or shifting of the base. Plots of these sections have no significance for the present so they are not included in this report. The data will, however, be included in a later report when additional cross-sections at these locations provide worthwhile comparisons.

* Computed as a percentage of the weight of coarse stone.

●BSERVATIONS AND CONCLUSIONS

Evaluation of vibrated macadam bases in general will require observations on additional projects involving stone having a better particle shape and screenings have a smaller maximum particle size. Also, experience with this method of construction will be necessary before all the merits can be shown. Within the limitations of this project it can be said that:

1. From the standpoint of density and smoothness of the compacted base, the vibratory method of construction produces results at least equal to those obtained with the conventional method of macadam base construction. In the latter stages of this project surfaces were as smooth as those built in the usual way.

2. The No. 1-A grading is satisfactory for vibrated macadam bases, but flat pieces of aggregate should be kept to a minimum since they are very difficult to key and they retard filling of the voids. In a similar way, undersize pieces (smaller than 1-1/2 in.) prevent proper filling of voids by blocking the passage ways through which screenings penetrate.

3. Coarse stone was spread satisfactorily with the equipment devised for this project, even though the crawler operated over stone previously placed. Further manipulation other than hand picking is undesirable after the stone has been mechanically spread. Similarly, operation of equipment (other than the vibrator over the loose stone should be avoided. In essence, the stone should have a minimum of disturbance prior to keying, and the desired section should be achieved before keying is started.

4. Keying can be best accomplished by use of the vibrating tamper without subsequent rolling. The tamper should be operated at its lowest forward speed (20 ft. per min.) for a single pass.

5. Application of screenings from tailgate spreader boxes results in segregation of coarse particles and erratic applications. A towed spreader box which accomplishes uniform distribution of screenings is preferable and should be required.

6. The vibrating tamper, operated at its lowest speed (20 ft. per min.), will accomplish filling of the voids in a single pass for each application of screenings. Open voids observed in the filled base could be directly attributed to flat particles of coarse stone, or blocking of voids by the larger particles of screenings. Apparently, the latter of these factors predominated, indicating a need for changes in specifications to reduce the maximum particle size.

7. A finer grading of screenings would be advantageous for the water binding of the last application of screenings, although that phase of the base construction was carried out satisfactorily on this project.

8. Measured densities of the vibrated macadam were relatively high (135.4 to 142.9 lb. per cu. ft.) in all but the early portions of the project. On the basis of general comparison with the usual water-bonding methods, vibratory compaction increases the percentage of screenings and consequently increases the density of the completed base.

9. The bituminous base course did not materially overcome the irregularities of the macadam base. In fact, it produced additional irregularities along the edges because of lateral shoving of the bituminous mix under the roller. This could be retarded by use of prime, at least near the edges.

There are several methods of eliminating, or at least reducing irregularities in the surface of the finished macadam base. Two of these methods seem worthy of consideration.

1. Employment of a fine graded (preferably a surface mix grading), hot-mixed, blade-spread mixture as a leveling course. This course, over a primed base, spread to an average depth of 1.0 in. by a motor grader would permit the advantageous use of a long wheel base in smoothing the surface of the base course. Blade spreading on this and previous projects indicates the feasibility of this work. Employment of fine graded mixtures makes application of thin courses practical. After initial steel-wheel rolling to set the mixture down, it would be an advantage to use pneumatic rolling to insure uniform compaction of this course. Such rolling reduces or eliminates the possibility of bridging by the steel-wheel roller and consequent surface settlement due to compaction by traffic.

2. Use of two stage base construction involving a dense-graded base course (3 to 4 in.) overlying the vibrated macadam base. This course would represent no sacrifice of strength and it too would permit the smoothing action of a long wheel-base spreader. There is precedence for this type of construction in Kentucky and elsewhere.

The above methods should result in improved riding surfaces in the finished pavement and still retain the advantages of one-course macadam base construction. Other methods may be available, however, these two appear to offer the best solution to the smoothness problem.

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