

95

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS



A COMBINATION WATERBOUND MACADAM AND DENSE-
GRADED AGGREGATE BASE FOR FLEXIBLE PAVEMENTS

for

32nd Annual Highway Research Board Meeting

by

W. B. Drake
Research Engineer

January, 1953

KENTUCKY TRANSPORTATION CENTER
LIBRARY

HIGHWAY MATERIALS RESEARCH LABORATORY
University of Kentucky
Lexington

KRR
95

c.1

A COMBINATION WATERBOUND MACADAM AND DENSE-
GRADED AGGREGATE BASE FOR FLEXIBLE PAVEMENTS

by

W. B. Drake
Research Engineer
Kentucky Department of Highways

SYNOPSIS

This paper is concerned with a flexible base designed primarily to improve the riding qualities of high-type bituminous pavements. Difficulties in control of grades and sections with modern methods of macadam base construction have emphasized needs for effective finishing procedures.

In the project described, an 8-in. base was built in two courses, the lower waterbound macadam being overlain by a dense-graded aggregate material suitable for spreading and shaping with a power grader. The base was then surfaced with two courses of a hot bituminous plant mix.

Observations and measurements showed that the combination could be built satisfactorily; construction entailed more equipment but less manpower for the blade-spread course than for the waterbound macadam; the dense-graded aggregate produced a high base density; and the possibilities for finishing to uniform section were much better with the dense-graded aggregate than with the macadam.

Introduction

Traditionally, the majority of bases in flexible pavement construction in Kentucky have consisted of waterbound macadam. Experience with it carries back over a period of more than 40 years. Within the past 5 years definite thickness design criteria based on subgrade bearing values and prevailing traffic have been developed. Those criteria, and the research through which they originated, were described in a paper presented at the 28th Annual Meeting of the Highway Research Board, 4 years ago. (1)

From the standpoint of load-bearing capacity, pavements of this design have been satisfactory. From the standpoint of riding qualities, however, they have been unsatisfactory - particularly those built recently. Through investigation of many projects built since the war, poor riding qualities were traced to difficulties in maintaining consistent transverse sections during construction of the waterbound macadam base.

Variations in the base course were, for the most part, reflected in the finished pavement surface. This was so because of the fact that equipment placing each of the overlying bituminous courses

(1) Baker, R. F., and Drake, W. B., "Investigation of Field and Laboratory Methods For Evaluating Subgrade Support in the Design of Highway Flexible Pavements," Proceedings, Highway Research Board, Vol. 28, 1948.

traveled upon the course beneath it - beginning with the base. Hence the contour of the finished base had a direct bearing on the contour of the finished surface, unless adjustments of the screed on the bituminous paver could be made to compensate for the unevenness.

Experience showed that it was not feasible to smooth out high and low spots in the base even with so-called leveling or crown-control mechanisms that have been developed for paving equipment. In fact, additional roughness was sometimes introduced through excessive manipulation of controls in an effort to achieve uniformity of crown. At any rate, since the fault lay in the base, attention was centered on that part of the pavement. Roughness so prevalent now was attributed to several factors which were not represented in pre-war construction. Most prominent among these was the speed in place-

ment of base material. The rate has practically doubled in the past ten years. As in all other types of construction speed is emphasized and within reason this seems necessary to keep costs as low as possible.

In addition to speed, there were scarcities of personnel and also the increased cost of labor both for controlling the sections and for applying the hand work necessary to maintain uniformity in surface contour of macadam containing very coarse aggregates.

In view of all these conditions, it was evident that any means for overcoming the problem must be mechanized and essentially eliminate hand labor. Also, it must carry forward in such a way that measurements for control could be kept at a minimum. However, since

some irregularities resulting from fast-moving construction were almost inevitable, the procedure should be such that those flaws detected could be smoothed out easily. Finally, all the other desirable attributes including strength or stability of the base must be maintained.

One of the approaches which has been made by the Kentucky Department of Highways to overcome roughness is a combination base in which the waterbound macadam was retained as a foundation and topped with a dense-graded crushed aggregate small in top size. This paper gives a description of the first of four projects with combination bases that were in the construction program this past year, and describes some of the data which have been obtained from observations and measurements on the project.

Design

The project, which was only 1.1 miles in length, essentially provided a connecting link between two principal highways, at the edge of an urban area, just south of Lexington. Finished pavement width was 30 ft., and thickness design for the pavement was based on the CBR Method developed several years ago and applied to the Flexible Pavement Design Evaluation's carried out in 1948.

From the 1948 investigation of subgrade bearing values beneath pavements in service, the curves shown in Fig. 1 were developed. These are used for standard flexible pavement design by the Kentucky Department of Highways. The five curves represent five groupings of traffic in equivalent 5000-lb. wheel loads. Anticipated

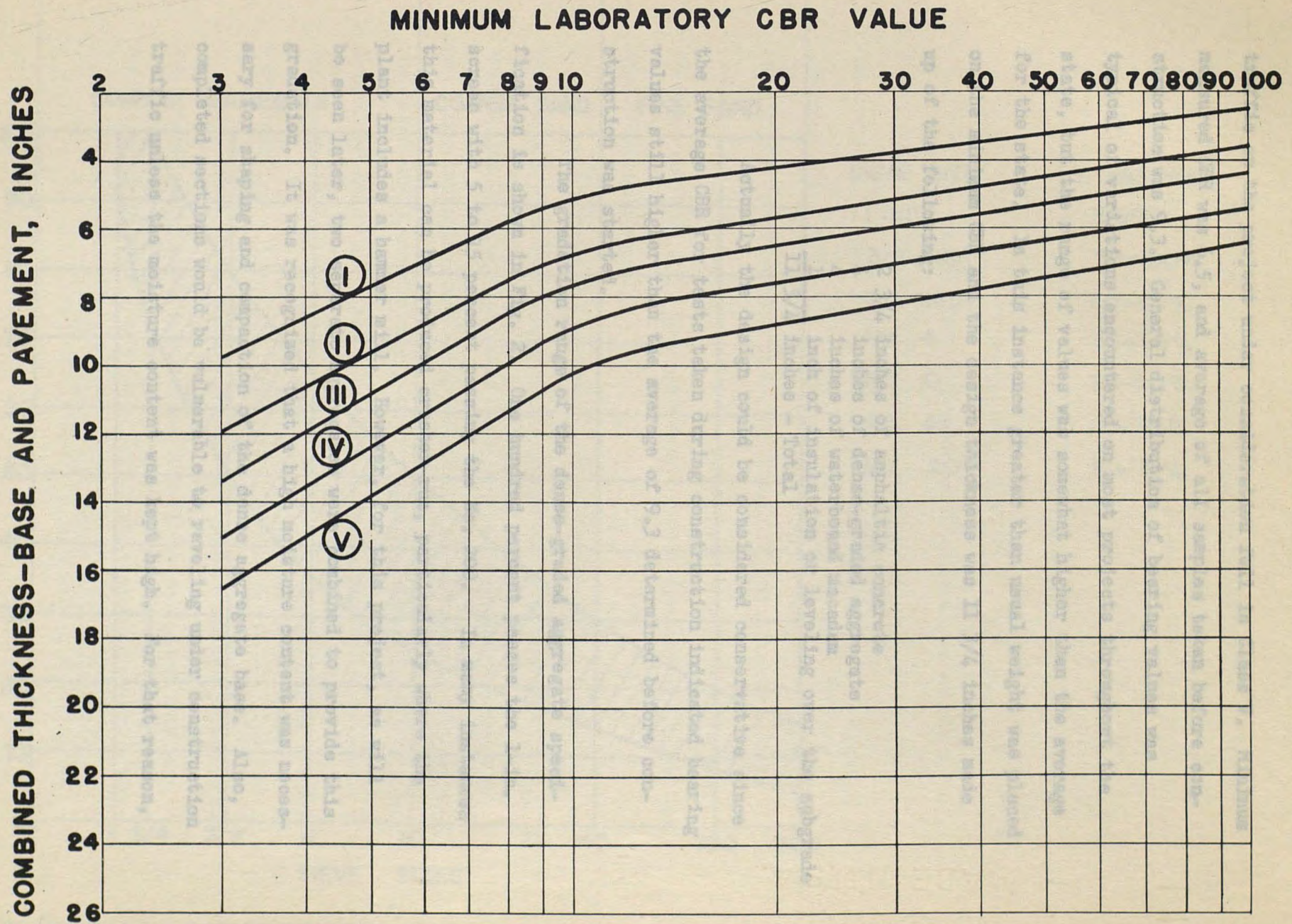


Fig. 1. Flexible pavement design curves.

traffic on the project under consideration fell in Class V. Minimum measured CBR was 6.5, and average of all samples taken before construction was 9.3. General distribution of bearing values was typical of variations encountered on most projects throughout the state, but the range of values was somewhat higher than the average for the state. In this instance greater than usual weight was placed on the minimum CBR and the design thickness was 11 3/4 inches made up of the following:

2 3/4	inches of asphaltic concrete
4	inches of dense-graded aggregate
4	inches of waterbound macadam
1	inch of insulation or leveling over the subgrade
11 3/4	inches - Total

Actually the design could be considered conservative since the average CBR for tests taken during construction indicated bearing values still higher than the average of 9.3 determined before construction was started.

The gradation range of the dense-graded aggregate specification is shown in Fig. 2. One hundred percent passes the 1-in. screen with 5 to 15 percent passing the No. 200. In many instances this material can be produced crusher-run, particularly where the plant includes a hammer mill. However, for this project, as will be seen later, two separate aggregates were combined to provide this gradation. It was recognized that a high moisture content was necessary for shaping and compaction of the dense aggregate base. Also, completed sections would be vulnerable to raveling under construction traffic unless the moisture content was kept high. For that reason,

Fig. 2. Aggregate gradation range for dense-graded base course.

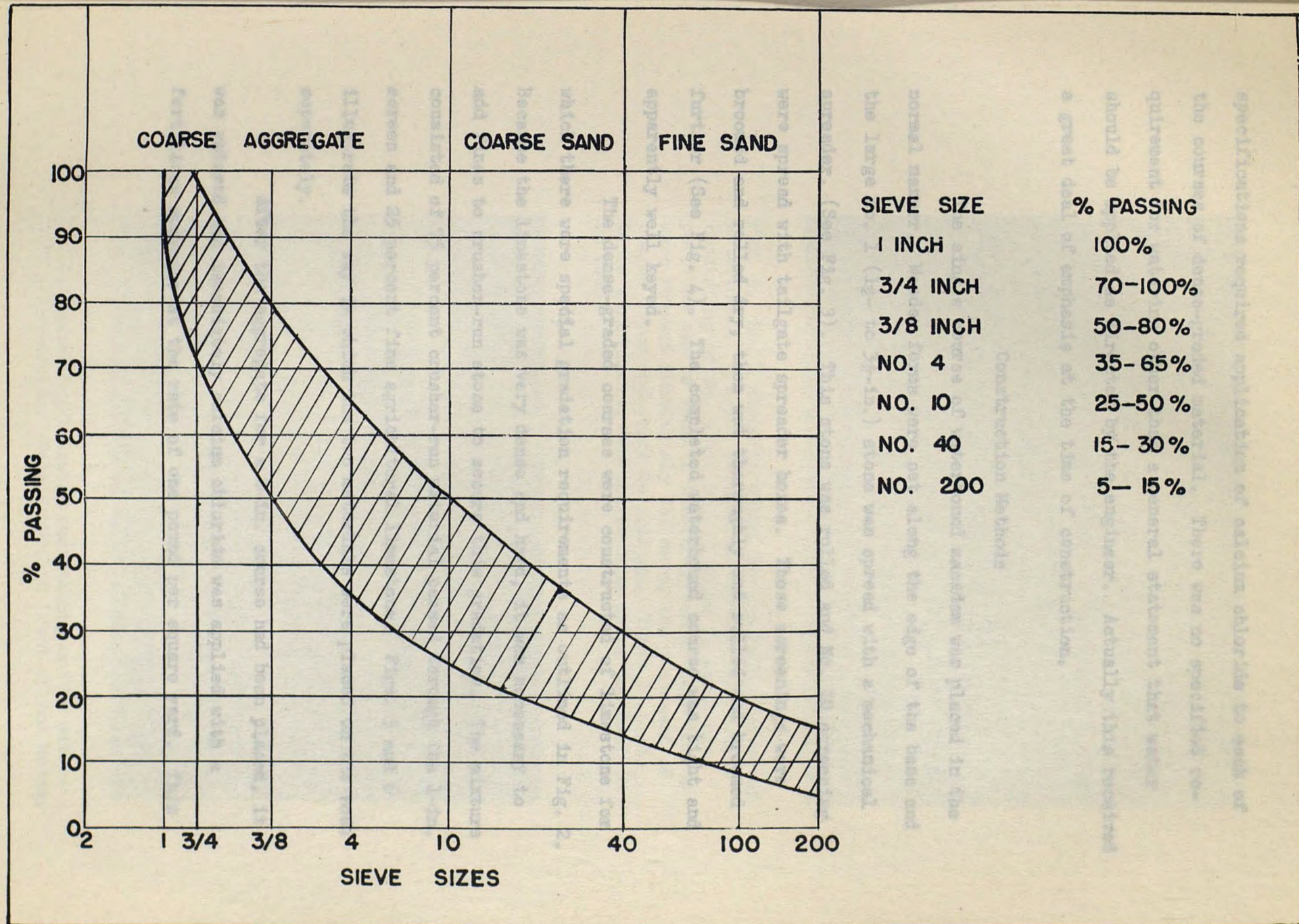


Fig. 2. Aggregate gradation range for dense-graded base courses.

specifications required application of calcium chloride to each of the courses of dense-graded material. There was no specified requirement for watering other than a general statement that water should be applied as directed by the engineer. Actually this received a great deal of emphasis at the time of construction.

Construction Methods

The single course of waterbound macadam was placed in the normal manner. Wooden forms were set along the edge of the base and the large No. 1 ($1\frac{1}{2}$ - to $3\frac{1}{2}$ -in.) stone was spread with a mechanical spreader. (See Fig. 3). This stone was rolled and No. 10 screenings were spread with tailgate spreader boxes. These screenings were broomed and rolled dry, then wet thoroughly and rolled and broomed further (See Fig. 4). The completed waterbound course was tight and apparently well keyed.

The dense-graded courses were constructed of limestone for which there were special gradation requirements as outlined in Fig. 2. Because the limestone was very dense and hard, it was necessary to add fines to crusher-run stone to secure this gradation. The mixture consisted of 75 percent crusher-run material passed through the 1-in. screen and 25 percent fine agricultural limestone. Figs. 5 and 6 illustrate the way in which the two materials were placed on the road separately.

After the aggregate for a 2-in. course had been placed, it was watered and immediately calcium chloride was applied with a fertilizer spreader at the rate of one pound per square yard. This

Fig. 4. Watering, brooming and rolling on the water-bound construction. Note slurry in front of the broom.

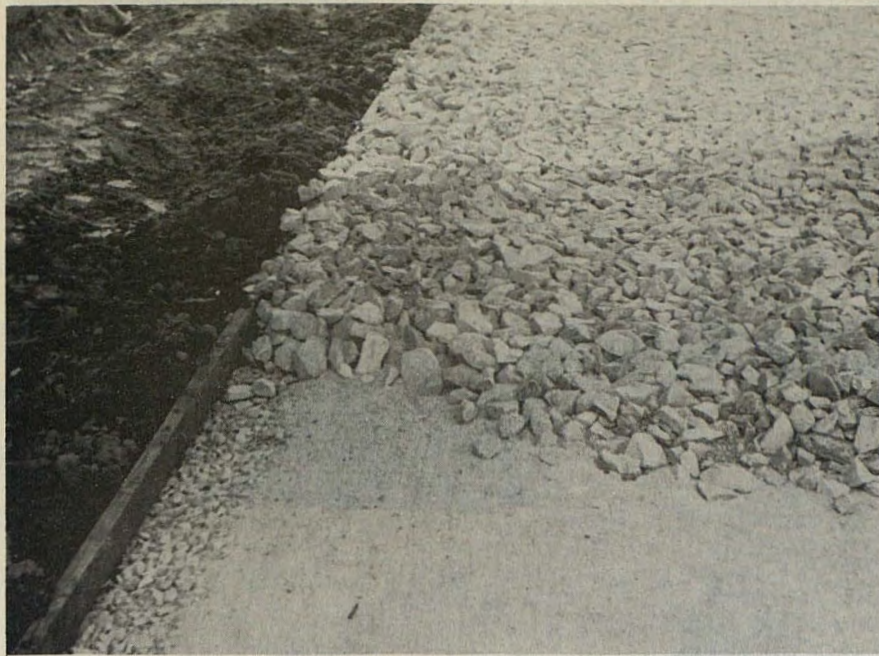


Fig. 3. No. 1 stone in place for the 4-in. course of waterbound. A 1-in. insulation and leveling course consisting of No. 5 and No. 10 stone in equal proportions can be seen in the foreground. Edge boards were removed immediately following the placement of coarse stone and prior to rolling. Three 10.5-ft. lanes were placed, the center lane being the last to go down.



Fig. 4. Watering, brooming and rolling on the water-bound construction. Note slurry in front of the broom.

operation is...
 made for each...
 obtained by...
 Mixing...
 chloride app...
 road, then...
 was rolled...
 water was...
 a dry concrete mix, with...
 Usually after the window had been...
 thorough mixture was obtained.

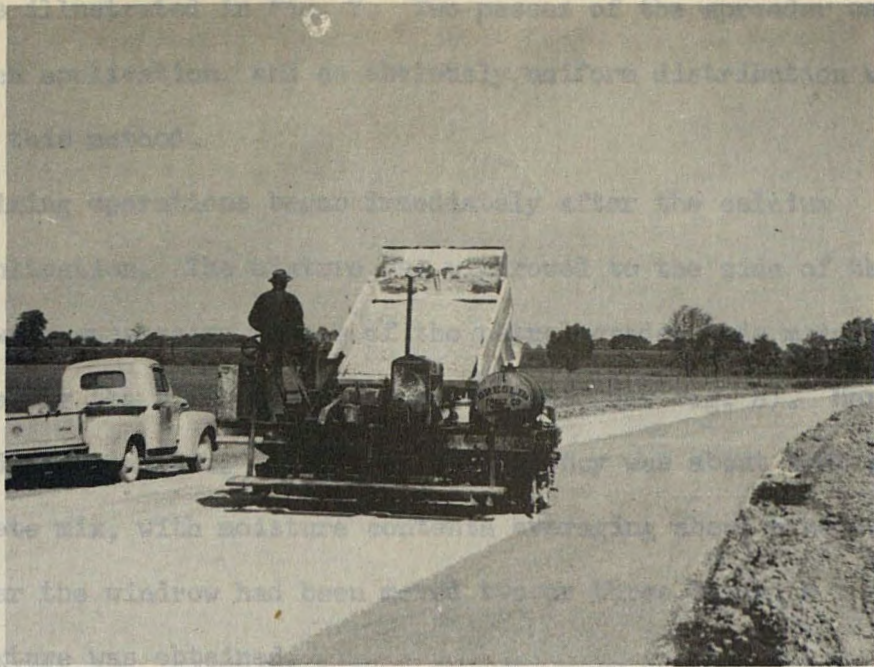


Fig. 5. Spreading the coarser of two aggregates used for the dense-graded base course construction. This stone was crusher run through a 1-in. screen with approximately three percent passing the No. 200 screen.

laid out. This...
 mold board of the mix...
 process, a...
 only for construction...
 through from the water...
 the blade-spread...
 out readily...
 blading" for...
 carried to...
 base was...
 roller in...
 wheel roller...
 allowed to...

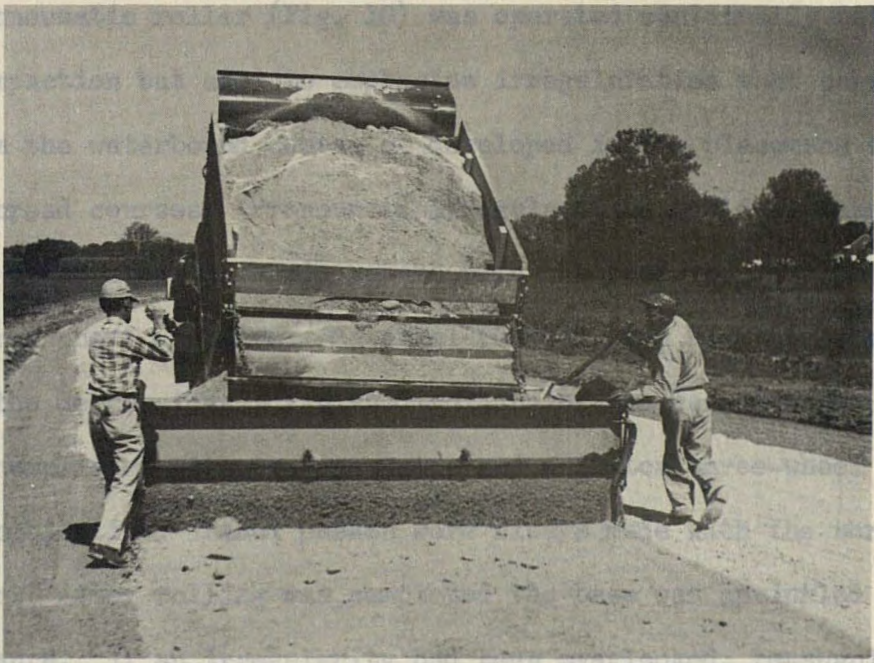


Fig. 6. Placing finer aggregate for the dense-graded course over the crusher run material shown in Fig. 5. Because of the insufficient quantity of material finer than the No. 200 mesh in the first stone placed, it was necessary to add fines which are normally sold for agricultural lime from this quarry. This fine fraction represented 25 percent of the total aggregate.

operation is illustrated in Fig. 7. Two passes of the spreader were made for each application, and an obviously uniform distribution was obtained by this method.

Mixing operations began immediately after the calcium chloride application. The mixture was windrowed to the side of the road, then with successive passes of the patrol grader this material was rolled along the blade to the opposite lane (See Fig. 8). More water was added as needed. The final consistency was about that of a dry concrete mix, with moisture contents averaging about 8 percent. Usually after the windrow had been moved two or three times, a thorough mixture was obtained.

Material was then brought to the center of the road and laid out. Edges were kept straight by using an edger attached to the mold board of the blade as shown in Fig. 9. During the laying out process, a pneumatic roller (Fig. 10) was operated continually not only for compaction but also to emphasize irregularities that carried through from the waterbound course or developed in the placement of the blade-spread courses. Pronounced irregularities could be taken out readily by turning the blade square with the road and "square blading" for a short distance. Material removed from high spots was carried to the depressions. Finished-rolling of the dense-graded base was accomplished with the pneumatic and a 10-ton three-wheel roller in combination. Final passes were always made with the three-wheel roller. After rolling was completed the base was sprinkled and allowed to cure. If an irregularity had been overlooked, re-shaping

Fig. 8. Mixing the stone, calcium chloride, and water with a patrol grader. The mixture was windrowed, then portions of the windrow were rolled along the blade across the road. Thorough mixing was accomplished after several passes with the patrol graders.



Fig. 7. Water was applied to thoroughly wet the stone prior to application of calcium chloride. This was done to assure an adequate moisture content and prevent segregation as well as facilitate manipulation during the mixing process that followed.

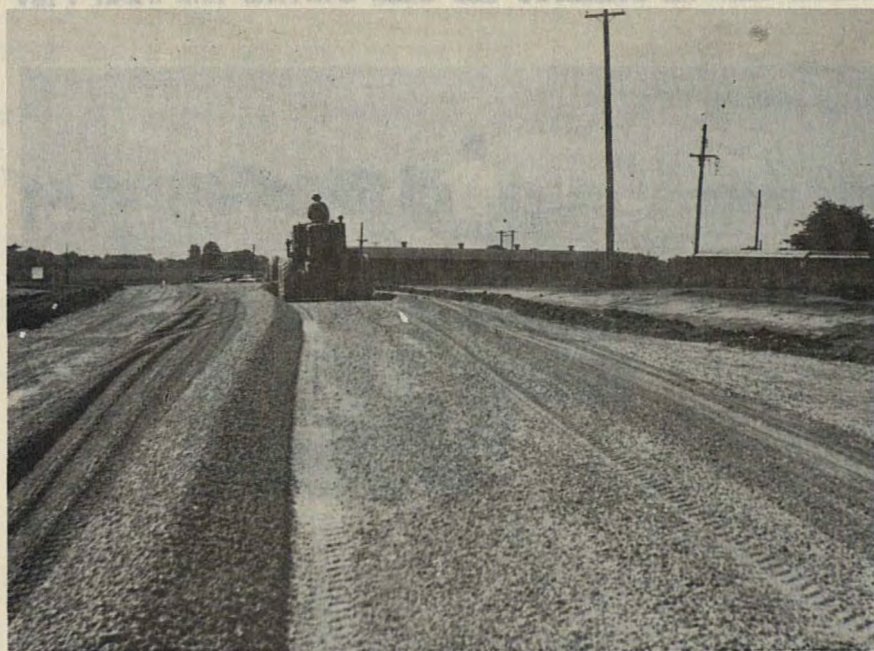


Fig. 8. Mixing the stone, calcium chloride, and water with a patrol grader. The mixture was windrowed, then portions of the windrow were rolled along the blade across the road. Thorough mixing was accomplished after several passes with the patrol graders.

and rolling as late as two days after placement was possible. It

was necessary

after re-shaping

rolled in a

finished the

There was no

and the beginning

of the second

far prices were

though there



Fig. 9. Placing the edge of the dense-graded base with an edge board that was attached to the blade for the last few passes in the layingout process. This attachment could be easily removed or replaced. A very neat and uniform edge was obtained in this manner.

satisfactorily there was an overrun of 2240 gal. in the prime

Application of the prime is illustrated in Fig. 10.

priming. C

nately 1 1/2

texture (K



Fig. 10. Pneumatic Rolling. This operation was begun during the final shaping of the blade-spread base.

and rolling as late as two days after placement was possible. It was necessary to wet the mixture thoroughly in order to recompact it after re-shaping.

The dense-graded base was placed, mixed, laid out, and rolled in approximately 2000-ft. sections, with the first 2-in. course finished throughout the project before the second course was begun. There was no particular waiting period between completion of the first and the beginning of the second course; however, following completion of the second course a 10-day curing period was allowed before the tar prime was applied.

There was no brooming of the base prior to priming even though there was some floater material created by the reshaping operations in a few places and by passing traffic which used the road during the waiting period. One section about 1500 ft. in length had an unusual amount of floater, and in order to tack down that material satisfactorily there was an overrun of 2240 gal. in the prime. Application of the prime is illustrated in Fig. 11.

The binder and surface courses were placed shortly after priming. Coarse-textured hot mix binder material was placed approximately $1\frac{1}{2}$ in. thick. The surface course was a plant mix of medium texture (Kentucky Type B) approximately $1\frac{1}{4}$ in. in thickness.

Observations and Test Results

Observations and tests were directed mainly toward four aspects of the work:

1. Gradation of the stone in the dense-graded courses.
2. Density of the completed dense-graded courses.

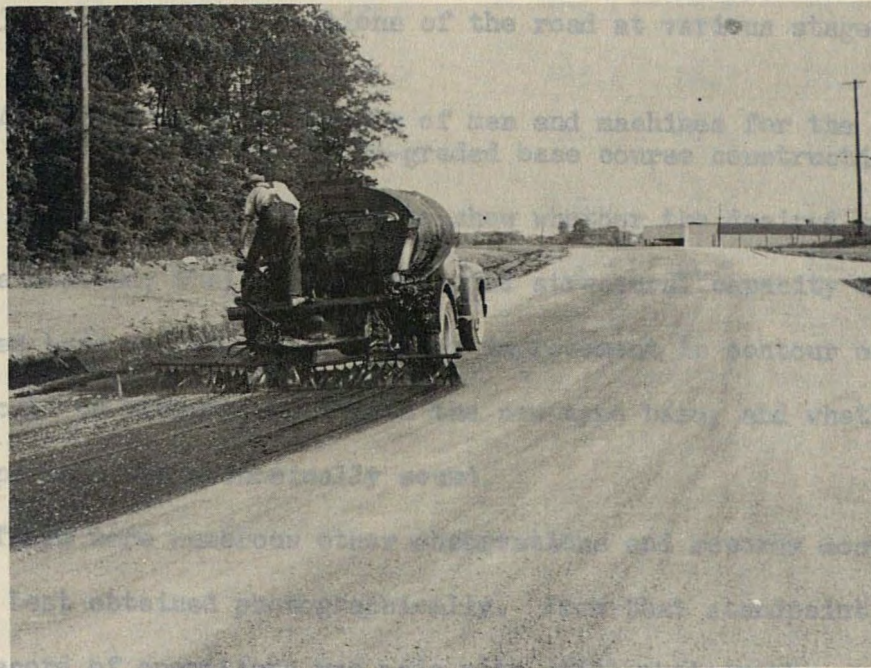


Fig. 11. Appearance of the finished dense-graded base at the time priming for the bituminous pavement was started.

Aggregate Gradation.

Gradation samples of the two aggregates used in the dense-graded mix, and samples of the mix itself, were taken at frequent intervals. Most of the fine aggregate samples were taken from stock-

Location (Station)	Date	Observations and Test Results	Lab. C.S.R.	L. L.	P. L.	H.S.B. Class
61/00	3-12	Observations and tests were directed mainly toward four			19.6	7-6 (10)
53/00		aspects of the work:	7.0	38.7	13.3	6 (7)
38/00	3-12	1. Gradation of the stone in the dense-graded courses.			12.8	6 (9)
23/00	3-12	2. Density of the completed dense-graded courses.			11.0	6 (5)
28/00	4-23	3. Profiles and sections of the road at various stages of construction.			20.4	7-6 (12)
56/00	4-23	4. Relative requirements of men and machines for the waterbound and dense-graded base course construction.	105.1	18.1	16.7	6 (11)
43/00	4-23				16.9	6 (11)

The intent of this information was to show whether the desired gradation could be maintained; whether the indicated structural capacity of the dense-graded base was adequate; whether improvement in contour of the pavement could be brought about with the new type base; and whether the new type base was economically sound.

There were numerous other observations and records most of which were best obtained photographically. From that standpoint a complete record of operations was made with still photographs, and in addition 16 mm. movies were taken from time to time as a means of realistically illustrating the important features of the work and the results produced. Finally, there were incidental tests - such as those pertaining to soils - which were included as part of the record.

Aggregate Gradation.

Gradation samples of the two aggregates used in the dense-graded mix, and samples of the mix itself, were taken at frequent intervals. Most of the fine aggregate samples were taken from stock-

Table 1. Soils Test Data

19

Location (Station)	Date	Sample No.	Proctor Max. Den.	Compaction Opt. MC	Field Density	Lab. C.B.R.	L. L.	P. I.	H.R.B. Class
61/00	3-12	1	98.6	23.5	-	6.5	46.6	19.6	7-6 (10)
53/00	3-12	2	99.8	22.3	-	7.0	38.7	13.3	6 (7)
38/00	3-12	3	100.9	22.6	-	12.2	35.6	12.8	6 (9)
23/00	3-12	4	104.2	20.5	-	11.5	35.2	11.0	6 (5)
48/00	4-23	1*	105.4	19.6	104.4	12.7	40.5	20.4	7-6 (12)
56/90	4-23	2*	105.1	19.2	105.1	18.1	37.8	16.7	6 (11)
43/00	4-23	3*	106.4	18.1	105.0	17.8	36.2	16.9	6 (11)
38/00	4-23	4*	112.2	16.4	110.6	7.8	39.5	24.3	6 (12)
33/00	4-23	5*	105.8	17.9	98.7	45.4	35.4	14.7	6 (10)
28/00	4-23	6*	109.0	17.7	111.1	16.1	35.6	15.4	6 (10)

* Reported by Division of Materials, May 28, 1952

After the fine aggregate had been spread and before water or calcium chloride had been applied, the total aggregate was sampled more or less as a control measure. In some instances outstanding gradation deficiencies were noted and it was necessary to blade some materials forward to minimize their effect on the composition of the final mix.

The greatest difficulties developed with the finer stone sizes early in the operations, but these were overcome through changes in the source of stone at one point and finally a change from No. 10 material to agricultural lime at the principal source of aggregate. For this type construction the percentage passing the No. 200 sieve was regarded as a critical factor and particular effort was made to

piles at the plant, but a few spot-check samples were taken from the trucks as they reached the job. The crusher-run aggregate was sampled after placement on the road, with the material being taken from a trench one shovel wide and running throughout the depth and width of the spread (usually a 10-ft. lane). This quantity was split successively until a test sample of reasonable size was obtained.

There was some segregation of the crusher-run aggregate in the trucks and this generally resulted in a concentration of coarser material early in the spread with a corresponding increase in fineness toward the end of the spread. Because of this, effort was made to take several samples from a selected spread. Also, in anticipation of this, it was decided at the outset to place the crusher-run aggregate in two passes of the spreader, and to that extent overcome segregation.

After the fine aggregate had been spread and before water or calcium chloride had been applied, the total aggregate was sampled more or less as a control measure. In some instances outstanding gradation deficiencies were noted and it was necessary to blade some materials forward to minimize their effect on the composition of the final mix.

The greatest difficulties developed with the finer stone sizes early in the operations, but these were overcome through changes in the source of stone at one point and finally a change from No. 10 material to agricultural lime at the principal source of aggregate. For this type construction the percentage passing the No. 200 sieve was regarded as a critical factor and particular effort was made to

keep this well above the minimum of 5 percent required by the specification.

Station	Course	1 In.	3/4 In.	3/8 In.	No. 4	No. 10	No. 40	No. 200
---------	--------	-------	---------	---------	-------	--------	--------	---------

45/00	5-6	100.0	97.5	82.2	58.2	29.9	12.9	8.5
30/00	5-7	100.0	97.3	80.8	53.3	29.6	13.2	6.7
25/00	5-7	100.0	97.6	83.6	61.1	28.9	13.0	7.0
12/00	5-8	100.0	98.6	79.3	54.6	28.6	14.2	8.9
44/00	5-9	100.0	97.0	74.1	53.8	31.0	14.4	9.2
36/30	5-12	100.0	97.6	77.7	52.3	29.5	13.3	8.7
32/00	5-12	100.0	99.3	84.2	77.0	49.1	20.6	12.0
11/50	5-12	100.0	98.4	91.4	75.5	48.1	20.1	11.7
60/00	5-15	100.0	100.0	90.5	72.4	48.8	23.6	14.7
55/00	5-15	100.0	100.0	89.5	67.7	42.8	20.9	14.0
50/00	5-15	100.0	100.0	90.7	68.6	40.1	18.2	11.3

45/ Density Determinations.

40/00 5-1 Measurements of density in the blade-spread courses were made at ten locations throughout the project, as listed in Table 3. For these determinations, holes approximately 3 inches in diameter were cut through the full depth of the dense-graded base by means of a hammer and chisel. All the material thus excavated was carefully saved, and the volume of the excavated hole determined by the rubber balloon method. Moisture contents were relatively low in comparison with those originally taken at the time of mixing. However, at the time these tests were made the base had been completed and three to seven days had elapsed since the materials had been placed and compacted. Variations in the recorded densities were not great con-

Note: First samples (taken 5-6 to 5-12) were from windrow of mixed aggregate. Base had been completed and three to seven days had elapsed since the materials had been placed and compacted.

Table 2. Gradation of Aggregate in Dense-Graded Base Courses

Station	Date	Percent Passing Sieve Sizes						
		1 In.	3/4 In.	3/8 In.	No. 4	No. 10	No. 40	No. 200
45/00	5-6	100.0	99.8	89.2	58.8	29.9	12.9	8.5
30/00	5-7	100.0	98.3	80.8	53.3	29.6	13.2	8.7
25/00	5-7	100.0	97.6	83.6	61.4	28.0	11.0	7.0
12/00	5-8	100.0	96.6	79.3	54.6	32.6	14.2	8.9
44/00	5-9	100.0	97.0	74.4	53.8	31.9	14.4	9.2
36/50	5-12	100.0	97.6	77.7	52.3	29.5	13.3	8.7
32/00	5-12	100.0	99.3	94.2	77.0	49.1	20.6	12.0
11/50	5-12	100.0	98.4	91.4	75.5	48.1	20.1	11.7
60/00	5-15	100.0	100.0	90.5	72.4	48.8	23.6	14.7
55/00	5-15	100.0	100.0	89.6	67.7	42.8	20.9	14.0
50/00	5-15	100.0	100.0	90.7	68.6	40.1	18.2	11.3
45/00	5-15	96.1	96.1	84.0	63.0	41.2	19.7	12.7
40/00	5-15	100.0	100.0	89.5	68.7	43.1	19.9	12.5
25/00	5-16	100.0	93.3	89.3	69.0	42.6	18.6	11.4
30/00	5-16	100.0	100.0	87.2	63.9	37.7	16.4	10.9
25/00	5-16	100.0	100.0	89.4	68.6	40.8	18.3	11.8
20/00	5-16	100.0	99.0	90.1	71.2	43.1	19.7	12.8
15/00	5-16	100.0	100.0	82.3	61.9	37.5	16.8	11.0

Note: First samples (taken 5-6 to 5-12) were from windrow of mixed aggregate. Remainder of samples were taken from completed base at time of density test.

Table 3. Measured Densities and Moisture Contents of Dense-Graded Base Courses.

Location (Station)	Dry Density (Pounds Per Cubic Foot)	Moisture Content (Percent Dry Weight)
15/00	153.0	3.07
20/00	145.1	2.77
25/00	152.5	2.95
30/00	148.3	2.79
35/00	151.3	3.00
40/00	161.8	2.64
45/00	152.1	1.61
50/00	150.0	1.47
55/00	157.4	2.42
60/00	159.7	2.99
Average	<u>153.1</u>	<u>2.57</u>

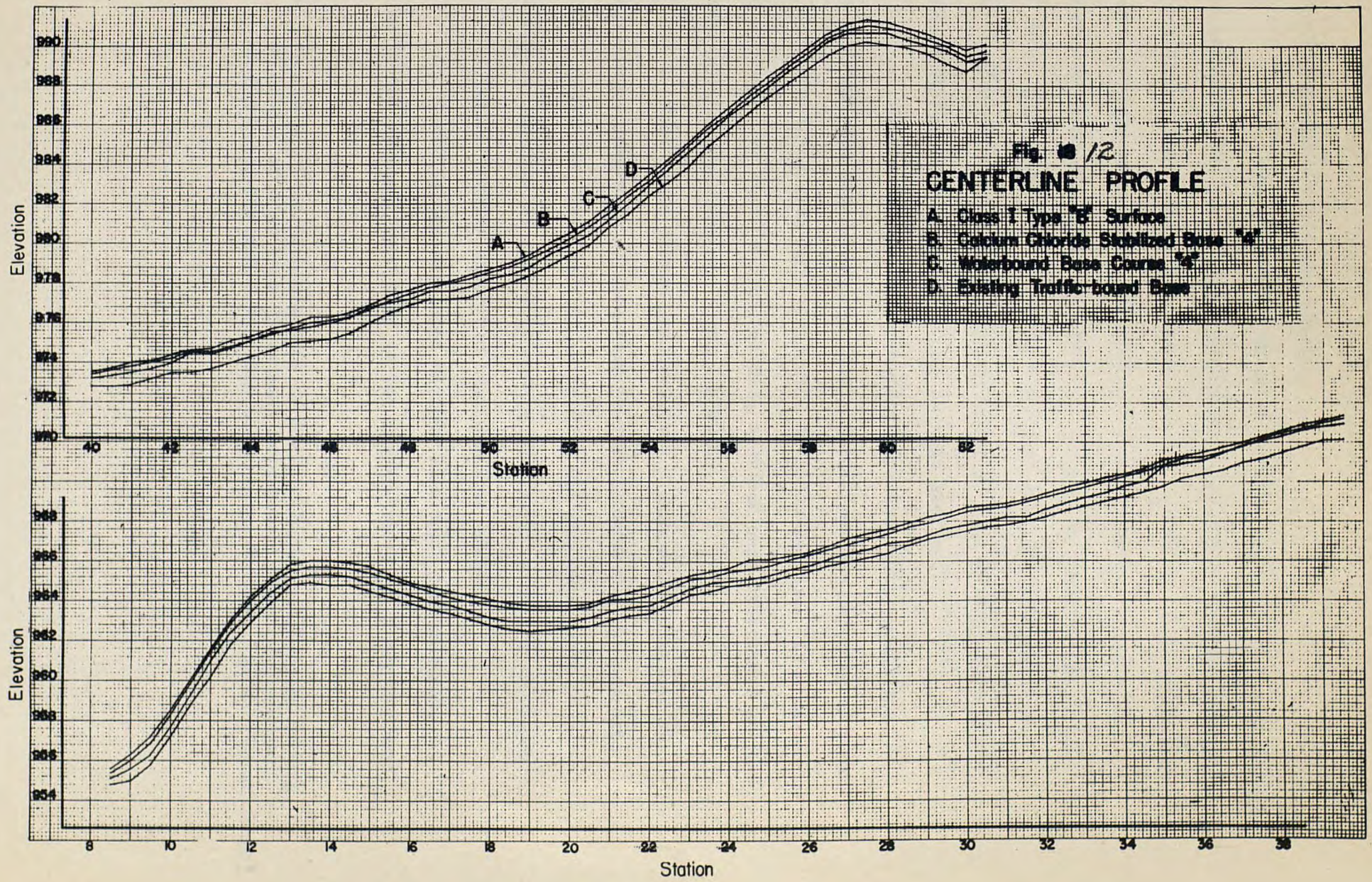
sidering the test limitations. Obviously the densities were high from any point of view. Calculated on the basis of percentage voids in the compacted aggregate having a specific gravity of 2.70, the condition of the base ranged from 4 to 13.8 percent and averaged 9.2 percent voids.

Profiles and Sections.

Center line profiles were taken every 50 feet at five different times during construction, and transverse sections were taken in detail at 50-ft. intervals within one 400-ft. section of the road. These measurements were to provide a basis for judging the effectiveness of each type of construction toward elimination of surface irregularities.

The center line profiles which were read to the nearest 0.1 ft. represented the top of the existing traffic bound prior to the beginning of pavement construction, and the elevations after completion of the waterbound course, the second dense-graded course, the bituminous binder course, and the bituminous surface course. A plot of four of these five sets of elevations is shown in Fig. 12. Those for the bituminous binder course were omitted in the interest of clarity.

Indications are that the blade-spread base did remove some pronounced irregularities of the waterbound and traffic-bound courses. However, the plots of Fig. 12 convey the impression that considerable irregularity remained after the blade-spread operations and even after



the bituminous surface was placed.

From the standpoint of actual riding qualities it is difficult to establish the significance of these slight irregularities when it is realized that they carry over a distance of 50 ft. Pavements with outstandingly poor riding qualities often have abrupt changes in elevation over distances that are hardly greater than the length of a car. Irregularities at longer intervals can give an undulating or "roller coaster" effect. The profiles of Fig. 12 show that there are no irregularities of that type in this surface.

Studies of surface irregularities and riding qualities (2) in the past few years have positively identified the majority of poor riding qualities with inconsistencies in cross section. As a means of checking for such inconsistencies, sections were determined at 50-ft. intervals between Stations 33,400 and 37,400.

Here again it was realized that pronounced variations in sections at intervals of less than 50 feet account for the poorest riding qualities, but limitations in time and personnel made it a choice of sections at closer intervals throughout a 100-ft. distance or sections at greater intervals over a longer distance.

A stringline stretched between blue tops, and measurements down to the surface, were used in the determination of cross sections.

- (2) Report No. 2 on "Measurements of Surface Irregularities and Riding Qualities of High Type Bituminous Pavements," Kentucky Department of Highways, Materials Research Laboratory, December, 1950. (Unpublished)

Measurements to the nearest $1/8$ inch were made on the top of the waterbound course, the top of the second dense-graded course, and the finished pavement surface. Plots of the sections are contained in Fig. 13.

Invariably the blade-spread courses had a contour which was much more uniform than the contour of the waterbound course, and almost invariably the newly formed surface more nearly approached the theoretical design section that the finished pavement was supposed to meet. In one or two instances there was very little crown in the dense-graded courses.

Generally speaking, two passes of the paver laying the bituminous courses did not improve the sections. At Stations 35+50, and 36+50, the sections of the finished pavement were decidedly poorer than the corresponding sections of the blade-spread base. It appears that settings of the paver screed were unnecessarily altered at these locations, particularly on operations in the center lane. Despite this and other influences, the few measured sections indicate that with the blade spread courses in place the paver had a better surface on which to operate than it would have had with the waterbound course alone.

Manpower and Machinery.

Insofar as possible, records were made to determine the equipment and personnel requirements for construction of each of the two types of base. Approximately the same quantity of stone was

Fig. 13. Cross sections taken over waterbound base course, dense-graded aggregate base course, and bituminous surface. Pavement with the 10-ft. dense-graded base design was 4-in. bituminous binder and surface thickness was 2 1/2-in.

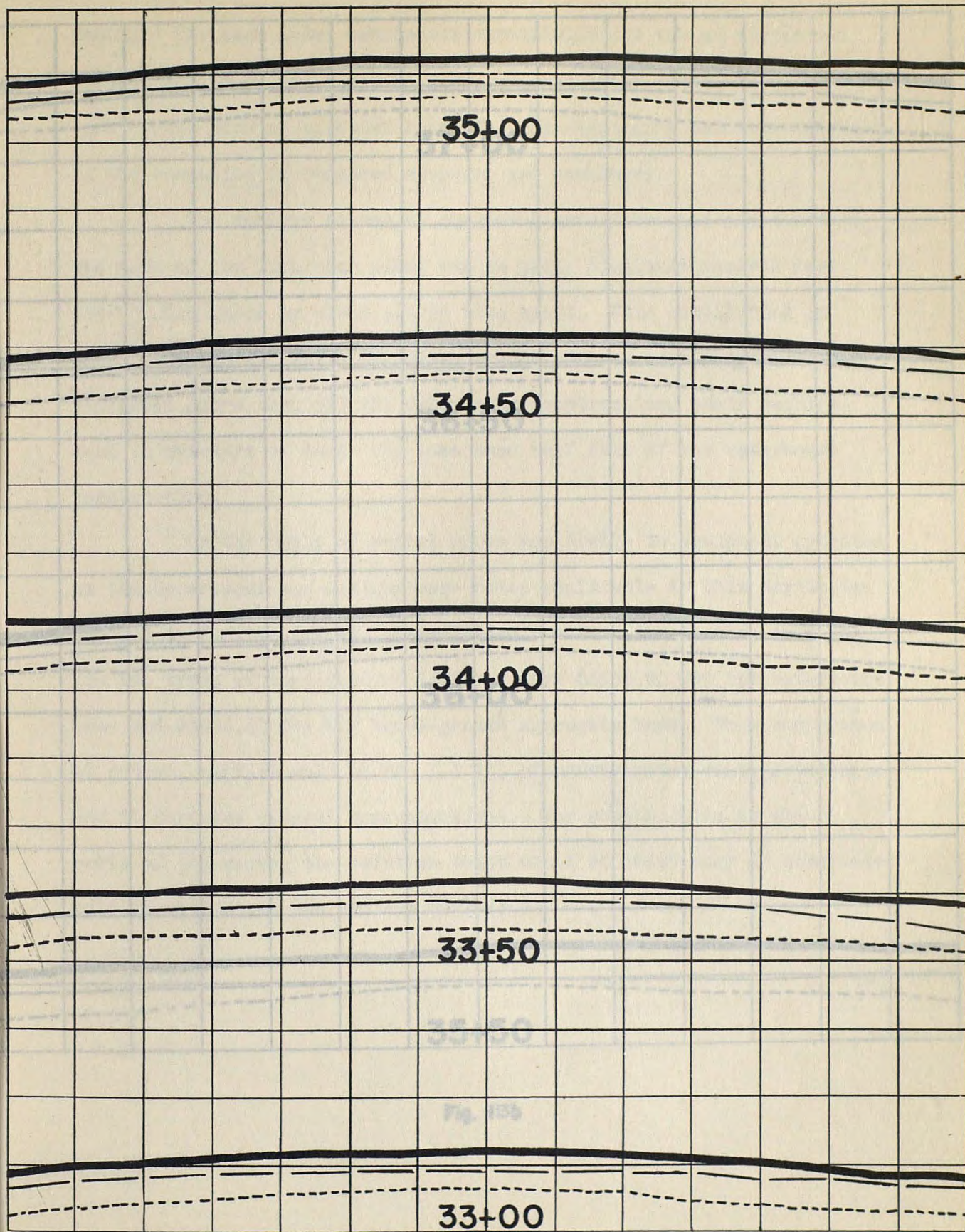


Fig. 13. Cross sections taken over waterbound base course, dense-graded aggregate base course, and bituminous surface. Pavement width was 30-ft.; dense-graded base design was 4-in.; bituminous binder and surface thickness was 2 3/4-in.

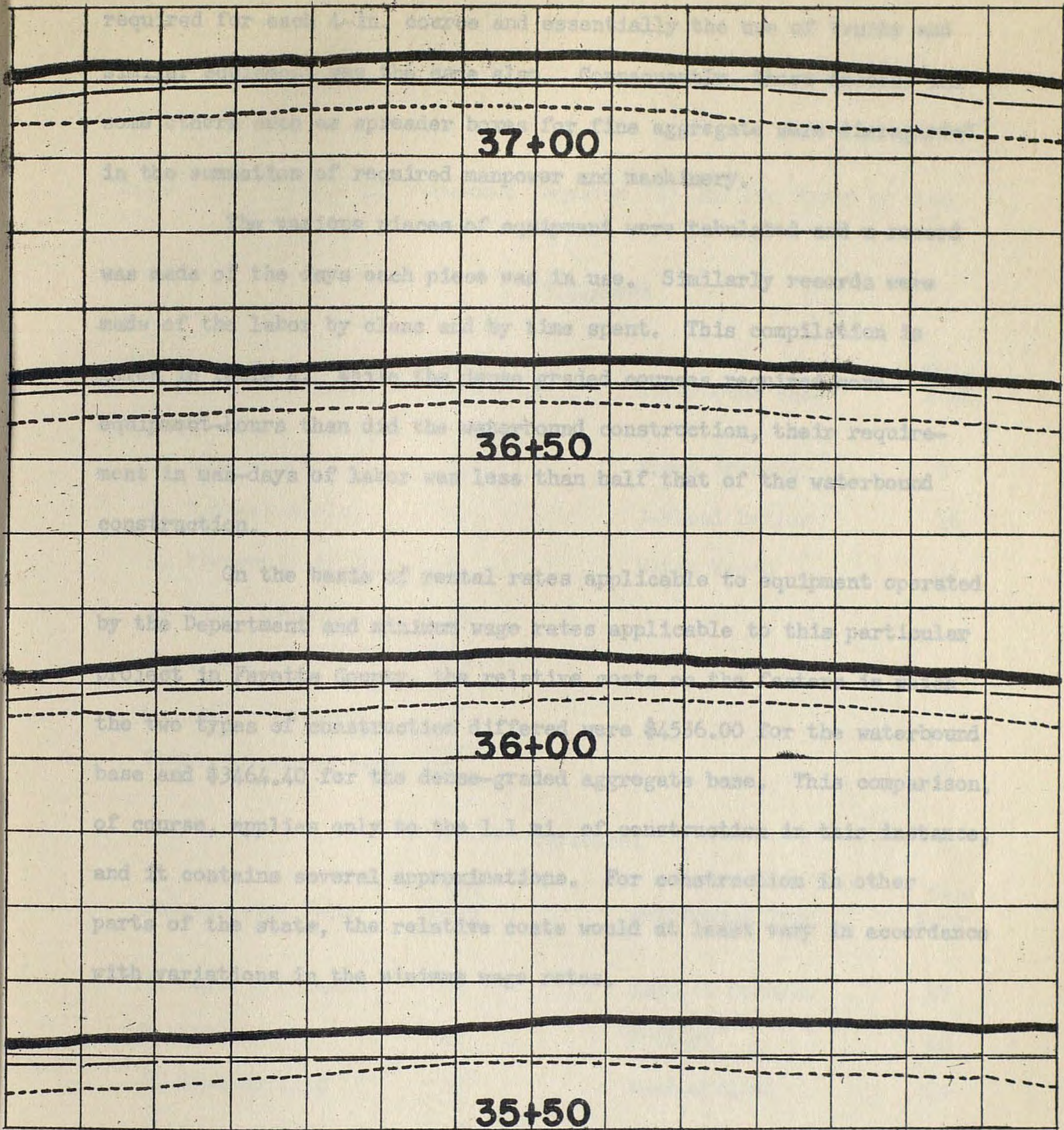


Fig. 13b

required for each 4-in. course and essentially the use of trucks and similar equipment was the same also. Consequently, these factors and some others such as spreader boxes for fine aggregate were disregarded in the summation of required manpower and machinery.

The various pieces of equipment were tabulated and a record was made of the days each piece was in use. Similarly records were made of the labor by class and by time spent. This compilation is given in Table 4. While the dense graded courses required more equipment-hours than did the waterbound construction, their requirement in man-days of labor was less than half that of the waterbound construction.

On the basis of rental rates applicable to equipment operated by the Department and minimum wage rates applicable to this particular project in Fayette County, the relative costs on the factors in which the two types of construction differed were \$4536.00 for the waterbound base and \$3464.40 for the dense-graded aggregate base. This comparison, of course, applies only to the 1.1 mi. of construction in this instance, and it contains several approximations. For construction in other parts of the state, the relative costs would at least vary in accordance with variations in the minimum wage rates.

2. Skilled	28	Skilled	28
3. Semi-skilled	87	Semi-skilled	87
4. Unclassified	27	Unclassified	27
Total Man Days	142	Total Man Days	142

Table 4. Equipment and Personnel Required For The Two Types of Base

Equipment			
Dense-Graded Base	Days Used	Waterbound Base	Days Used
1. Adnun Spreader	7	Apsco Spreader	9
2. 3-Wheel Roller	8	3-Wheel Roller	16
3. Pneumatic Roller	8	Water Wagon	11
4. Water Wagon	17		
5. Grader	13		
6. CaCl ₂ Spreader	5		
Total Equipment Days	<u>58</u>		<u>36</u>

Personnel			
Dense-Graded Base	Man Days	Waterbound Base	Man Days
1. Supt. & Foreman	17	Supt. & Foreman	27
2. Skilled	28	Skilled	46
3. Semi-skilled	27	Semi-skilled	65
4. Unclassified	37	Unclassified	85
Total Man Days	<u>109</u>		<u>223</u>