Design and Construction of Test Sections on U. S. Highway No. 31

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SYNOPSIS

The 1953 Indiana Test Road was built in south-central Indiana for the purpose of comparing flexible and rigid pavements as authorized by the Indiana legislature. The pavements are connecting and have the same soil types and conditions, and are subjected to similar traffic.

Both the Portland Cement Association and the Asphalt Institute, were asked to make suggested recommendations for the design and construction of their respective projects, with the stipulation that if their suggested recommendations meet with the approval of the Highway Department, they would be incorporated in the contract.

The thickness of the concrete pavement is in accordance with the Portland Cement Association’s publication titled, “Concrete Pavement Design.” The section consists of a nine inch uniform concrete pavement on a dense graded granular subbase of either five or six inches depending on the subgrade soil type.

The flexible pavement design was based on CBR curves developed by the U. S. Army Corps of Engineers, and soil group index thickness criteria, as developed by the Bureau of Public Roads. The section selected was five inches of bituminous material on eight inches of water-bound macadam with six and one-half inches of open graded, granular subbase—a total thickness of 19 ½ inches.

The rigid section was constructed using normal equipment. The flexible section stipulated the use of a heavy pneumatic compactor and a multiple shoe vibrator.

Both projects are well designed, and well built, with an intensive testing program followed throughout construction. These projects should accomplish the original intent of evaluating the characteristics of the two pavement types.
On February 8, 1951, the Senate in the 87th Regular Session of the General Assembly passed Senate Concurrent Resolution No. 11. Portions of this resolution as stated in chapter 335 of the 1951 acts are as follows: "the State Highway Commission be charged and authorized hereby to conduct adequate and conclusive tests of both materials under exact circumstances, laying stretches of each directly connecting, or in such manner as will feasibly effect the desired results of this test and be prepared to report to the 1953 General Assembly its true progress and exact findings to date as to durability, lasting qualities under heavy truck and auto traffic and relative costs of initial application and general upkeep of each."—"That the studies, comparisons, and experimentations herein contemplated be undertaken as soon as may be practicable in the circumstances and that the results, conclusions and recommendations pertaining thereto be made available to the public."

In compliance with this resolution the State Highway Department of Indiana selected US highway #31, from 1.8 miles northwest of Columbus to 2.8 miles north of the Bartholomew-Johnson county line, as the site for this comparison of pavement types.

DESCRIPTION OF TEST SECTIONS

The south portion of this site from 1.8 miles northwest of Columbus to 2.3 miles south of the Bartholomew-Johnson county line was selected as the location for the bituminous concrete pavement. A portion of the southern end of this section, having a net length of 1.126 miles, is designated as FI 722 (4) Paving, and the remainder or majority of this section, with a net length of 4.172 miles, is designated at FI 81 (8) Paving. The combined total net length of the bituminous project is 5.298 miles. The flexible pavement was constructed under Contract R-3502.

The north portion of this site beginning 2.3 miles south of the Bartholomew-Johnson line, or from the north end of the bituminous concrete paving section, to 2.8 miles north of the county line was selected as the location for reinforced concrete pavement. This project, which has a net length of 5.117 miles, is designated as FI 81 (12) Paving. The reinforced concrete was constructed under Contract R-3503.

Before the construction of the test road, US #31 through this area was a two lane concrete pavement. Except for the relocation around Edinburg, the original concrete was completed in 1927 as 9-7-9 pavement 18 feet wide, without transverse joints. Later portions of this pavement were widened with concrete to 24 feet. The reloca-
Fig. 1. Location of test road.
tion around Edinburg was constructed about 1943, during a critical steel shortage. This later section was built with transverse joints spaced at 20 foot intervals and without load transfers. In general the performance of the old pavement was good. However, considerable faulting did occur at the transverse joints on the section around Edinburg. Faulting in this area was not due to pumping, since most of the subgrade consisted of in-place granular mixtures, but could be attributed to a lack of adequate load transfers.

The construction of the test road sections and the additional work required under the two contracts, made this part of US #31 dual pavements and provided a new connection with US #31 alternate. These contracts included a bituminous resurface for the old concrete pavement where it remained in-place and now serves as a part of the dual pavement. This paper will not discuss any of the bituminous resurfacing but will be limited to new construction of the test pavement.

The test sections are all new construction. Both types of pavement were constructed on both the north and south bound pavements on each of the contracts. On the south contract 4.30 miles of new bituminous concrete was constructed in the south bound pavement and 2.82 miles in the north bound pavement, for a total of 7.12 miles. On the north contract 2.84 miles of new portland cement concrete was constructed in the south bound pavement and 4.10 miles constructed in the north bound pavement for a total of 6.94 miles. Construction limits in each of the pavements are shown in figure 2.

**PRE GRADING**

On July 11, 1950, contract R-3234, for grading and drainage, was awarded by the Highway Department to Morris Prosser of Franklin, Indiana. This contract covered grading and drainage for most of the proposed new pavement for FI Projects 722 (4), 81 (8) and 81 (12), beginning 0.31 mile south of the junction with US #31A, north of Columbus, and continuing north a distance of approximately 9.60 miles to a point 2.8 miles north of the Bartholomew-Johnson County line.

Grading operations were controlled by item B502.2 of the Standard Specifications which requires a minimum compaction of 95 per cent of maximum density for all soils except granular mixtures meeting the requirements for grade "B" special borrow; in the latter case a minimum compaction of 90 per cent of maximum density was required.

The grading contract specified June 1, 1951, as the completion date for this work. However, the last day of work for this contract...
Fig. 2. Location of test sections.
was May 21, 1952, almost one year later than the contract completion date.

The Soils Department started detailed investigation and sampling on February 6, 1951. This work was continued as the contractor's operation permitted. Whenever the contractor reached the proposed subgrade elevation in fill sections or graded to within a foot of the proposed subgrade in cut sections a soils investigation of the area was made. The completed soils data was transmitted January 30, 1952.

SOILS

Johnson and Bartholomew counties are located along the southern borders of the Wisconsin drift and are crossed by the Shelbyville and Champaign moraines. The project parallels the Wisconsin drift border for its entire length.

Pedologically the soil types are predominately Fox sandy loams or Homer silty clay loams. These materials are of glacio-fluvial origin and range from granular to almost impervious in texture.

The soil types and soil conditions on each of these two contracts are similar in all details. Soil types range from A-1-a, sands and gravels, to a plastic A-6(11) clay. Representative soil samples analyzed in our laboratory totalled 20 for the flexible section, and 24 for the rigid section. Based on the laboratory analysis the samples classified as follows:

<table>
<thead>
<tr>
<th>Highway Research Board Classification</th>
<th>Texture Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1-a</td>
<td>Sand and gravel</td>
</tr>
<tr>
<td>A-2-4</td>
<td>Sandy or sandy gravel</td>
</tr>
<tr>
<td>A-2-6</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>A-4(2)</td>
<td>Sandy loam or sandy clay loam</td>
</tr>
<tr>
<td>A-4(3)</td>
<td>Sandy loam or sandy clay loam</td>
</tr>
<tr>
<td>A-4(4)</td>
<td>Clay loam</td>
</tr>
<tr>
<td>A-4(5)</td>
<td>Loam</td>
</tr>
<tr>
<td>A-4(6)</td>
<td>Loam</td>
</tr>
<tr>
<td>A-6(1)</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>A-6(3)</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>A-6(8)</td>
<td>Clay loam</td>
</tr>
<tr>
<td>A-6(9)</td>
<td>Clay loam</td>
</tr>
<tr>
<td>A-6(10)</td>
<td>Clay loam</td>
</tr>
<tr>
<td>A-6(11)</td>
<td>Clay</td>
</tr>
</tbody>
</table>

The occurrence of these soil types both in their natural state and in the finished grade are quite variable. Some fill sections that require special borrow and overhaul are particularly variable. Some of the granular materials contain strata and striations of slightly varying textures and varying amounts of soil binder that are not practical to show
in detail on the soil profiles. Because of the many variations, soil borings were made to a minimum depth of three feet below proposed subgrade on centerline and 12 feet left and 12 feet right of centerline. The plotting of these borings and the identification of soil types in accordance with the laboratory analysis were shown in detail on the soil profile prepared for each contract.

These soil profiles were checked at the time of construction and are revised and extended where the grade was changed or where new grade was constructed.

In order to obtain additional design data for these various soil types, eight representative soil samples were selected for determining laboratory California Bearing Ratio values.

**TRAFFIC**

Traffic data for these test sections were supplied by the Highway Planning Survey. These data were arranged in tabular form showing the actual number of single axles of 10,000 pounds and over and tandem axles of 16,000 pounds and over, as weighed in August 1948, 1949 and 1950. Based on these data, similar tabulations were made showing the number and weight of axles using these pavements in a 24 hour annual average day for 1951. The tabulation shows slightly more traffic for the flexible pavement sections. In estimating the 1960 traffic (based on a 6 per cent increase) the operation of Camp Atterbury was not included. It is interesting to note that the largest number of axles fell in the weight groups that approximated the legal axle load limits. The 1951 estimate lists two single axles per day between 24,000 and 26,000 pounds and three tandem axles of over 36,000 pounds for the south section.

**ISSUANCE OF BASIC DATA**

All soils and traffic data were submitted to the Portland Cement Association and to the Asphalt Institute.

These organizations were asked to make suggested recommendations for the design and construction of their respective projects, with the stipulation that if their suggested recommendations meet with the approval of the Highway Department they would be incorporated in the contract.

With this background outlining the creation of the test sections, a description of the projects, and a brief summary of the soils and traffic data we are ready to discuss the design and construction features for each of the test pavements.
Selection of Subbase

With the exception of several localized areas, the texture of the subgrade or a plasticity index greater than six, established the need for a granular subbase. Soaked CBR specimens of subgrade material compacted to 95 per cent standard density established minimum CBR values of approximately 4.6 for A-2 and A-4 soils and 2.7 for A-6 soils. These values correspond to k factors of 150 and 100 respectively. The selected thickness of the granular subbase varies from six inches on all A-6 soils to five inches on all granular and A-4 soils. Since the total thickness of the pavement and subbase is not sufficient to prevent some frost penetration of the subgrade soil a subgrade modulus of k 100 was used for the pavement design.

Normally, Indiana's design for rigid pavements carrying a large volume of heavy axle loads permits the use of either type I (open graded) or a modified type II (dense graded) granular subbase material. However, if modified type II material is used the fraction passing the #200 is not to exceed 10 per cent. Although the permeability of these two materials may have a wide range the subbase course is designed for drainage and is provided with continuous outlets.

Because of the favorable soil conditions prevailing over most of this project and the availability of local aggregate Indiana's standard dense graded type II subbase material was recommended. The only change from our standard type II material was the additional requirement that the plasticity index be not more than six. Subbase extends

Fig. 3. Typical section of reinforced concrete pavement.
one foot beyond each edge of pavement and was placed in a trench section without drainage.

Pavement Section

Indiana's standard nine-inch uniform depth pavement, with a 1½-inch bilateral crown, reinforced with style 612-24 wire fabric placed two inches below the pavement surface, and our standard 40-foot transverse contraction joint spacing was adopted as the typical cross section. The thickness of the pavement is in accordance with Portland Cement Association's publication titled, "Concrete Pavement Design" (Revised December 1951).

Composition and Consistency of Concrete

Indiana's Standard Specifications for composition and consistency for air-entrained concrete was recommended. Experience has shown that satisfactory concrete, having an average modulus of rupture of 700 psi in 28 days (values used in determining the thickness of pavement) is obtained when these specifications are used.

Joints, Dowels and Tie Bars

Except for construction and special joints, all transverse joints are contraction joints spaced at 40-foot intervals in accordance with Indiana's standard practice.

Dowels for transverse joints are one-inch round, 20 inches long, spaced on 12-inch centers. Current Indiana design provided for one inch round bars, 24 inches long spaced at 12-inch centers.

All dowels were coated with tar paint prior to installation in the supporting assembly. Following installation the dowels were again coated with MC-2 liquid asphalt to break the bond.

Tie bars for longitudinal joints are one-half inch round deformed, 30 inches long spaced at 30 inch centers.

Tie bars for construction joints are five-eighths inch deformed round, 36 inches long spaced at 12-inch centers. All construction joints were edged and sealed in a manner similar to contraction joints.

Based on the Portland Cement Association's recommendations all longitudinal joints were sawed. The width of the joint to be not less than one-eighth inch nor more than three-sixteenth inch and the depth not less than 2½ inches. The joint seal was of the rubber-base type installed by a pressure applicator, capable of filling the joint from bot-
Requirements for Preparation of Subgrade

Prior to the construction of the subbase, all areas of the subgrade beneath and extending for two feet on each side of pavement were compacted or recompacted for a depth of at least six inches, to a measured density of not less than 95 per cent of maximum as outlined in AASHO Specification, Designation T99-49.

Compaction of Subbase

Subbase material was compacted to at least 95 per cent of maximum density (AASHO T99-49), except the density was based on the portion passing the 3/4 inch sieve instead of passing the No. 4 sieve.

Prior to the placing of the concrete and after the passage of the subgrade machine or subgrader or other equipment, the material had the required density as set out above.

Shoulder Construction Requirements

The following requirements for shoulder construction were deemed necessary to assure good performance of the type II subbase.

1. Shoulder material for the outside or through lane of pavement was constructed of earth or other approved material having a plasticity index of 10 or less and/or a volume change of 14 or less. This requirement did not apply to material for shoulder construction adjacent to the inside or passing lane.

2. All shoulder material extending from the edge of pavement to the shoulder line was compacted for a depth of nine inches to at least 95 per cent of maximum density (AASHO T99-49).

3. Prior to the placement of the shoulder material for the outside shoulders, all material used for edge curing of the pavement was removed and, if suitable for shoulder material, bladed transversely and spread on the shoulder subgrade away from the pavement. Shoulder material was of uniform quality and met the requirements as specified.

4. Sodding of the shoulders adjacent to the pavement was eliminated. Mulching and seeding was substituted.

Aggregate for Portland Cement Concrete

To insure the quality of the materials used in the concrete the Specifications required the following: “Aggregates from pits or quarries which have not given adequate and satisfactory performance in service, as established by the Engineer, shall not be used in portland cement concrete of this contract.”
Testing

To insure adequate control, compliance with specification requirements and to establish actual values for various items making up the completed test pavements, a very detailed and complete testing program was followed. Complete field laboratories were established on both contracts. Adequate and competent personnel were provided in order that we might have a very detailed record of all construction phases.

Construction Contract

Seven bids were received for this contract varying from the low bid in the amount of $751,451.69 to the highest bid in the amount of $892,666.23. Six of the bids were below the Engineer's Estimate, which was $867,949.77.

The contract was awarded to the low bidder, the Bontrager Construction Company of Elkhart, Indiana. This is a federal aid project.

RIGID PAVEMENT CONSTRUCTION

Subgrade

As stated earlier most of this project was pregraded.

No difficulties were encountered in obtaining the required subgrade densities with the standard compaction equipment. All of the subgrade was rolled with ten-ton three-wheeled rollers.

In general the densities ranged from 97 per cent to 105 per cent of standard.

Subbase

Subbase material was sand and gravel obtained from a local deposit adjacent to the right-of-way at a point approximately midway of the project. The material was produced by mixing and blending with dragline equipment at the pit. A large number of control tests were run on stockpiles at the pit to determine its compliance with specifications before hauling to the grade.

The prepared material was hauled to the grade by trucks, placed in two layers or courses, and each course compacted. Water was added as needed and final compaction obtained with three-wheeled 10-ton rollers.

Average gradation of the subbase material is as follows:

<table>
<thead>
<tr>
<th>Sieve sizes</th>
<th>1¼”</th>
<th>1”</th>
<th>¾”</th>
<th>½”</th>
<th>#4</th>
<th>#8</th>
<th>#30</th>
<th>#200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total % retained</td>
<td>0</td>
<td>2.5</td>
<td>4.5</td>
<td>7.5</td>
<td>21.1</td>
<td>32.0</td>
<td>60.4</td>
<td>91.0</td>
</tr>
</tbody>
</table>

The fraction passing the #40 sieve was non-plastic.

The average in-place density was 129.6 pounds per cubic foot. The
Fig. 4. Placing and compacting subbase material.

Fig. 5. Rolling subbase with a ten-ton three-wheeled roller after fine grading.
average in-place dry density was 101.3 per cent of standard, ranging from 96.2 per cent to 107.7 per cent.

The contract price for this material complete in-place was $1.80 per cubic yard.

**Mixing and Placing of Concrete**

A central proportioning plant was set up adjacent to the project at a point slightly south of the center of the project.

The aggregates used have shown prior satisfactory performance. Sources were as follows:

- Sand—Burnside Plant at Edinburg, Indiana.
- “L” Gravel—Burnside Plant at Shelbyville, Indiana.
- “U” Stone—France Stone Company at Greencastle, Indiana.
- Air-entraining portland cement was used.

The aggregates and cement were hauled in batch trucks to two 34E concrete mixers working in tandem on the shoulders.

Yield, air content, slump and water-cement ratio tests were run regularly for control tests. A minimum of three beams per day were made. Beams were broken at seven and 28 days to establish the quality of the concrete.

**Finishing Concrete**

The placing and spreading of the concrete was followed by the bull-float and finishing machine.

These operations were followed with the normal straight edging, belting, brooming, edging and joint finishing.

**Curing**

Following these operations the pavement was covered with burlap and kept wet until the morning of the following day.

The following day the burlap was removed and the pavement cov-
Fig. 7. Mixing and placing of concrete showing surface of prepared subbase and dowel assemblies.

Fig. 8. Placing and spreading of concrete.
Fig. 9. View behind the bull-float.

Fig. 10. Finished pavement surface and transverse contraction joint.
ered with straw. The straw was kept wet for the completion of the curing period or for a minimum of 96 hours in accordance with our standard specifications.

The contractor's bid for reinforced concrete pavement was $4.37 per square yard.

*Sawed Longitudinal Joint*

The longitudinal joint was sawed with a Felker-DiMet power-driven cutter after the straw cure was removed.

The contract price for sawing of this joint, including furnishing and placing of sealing compound, was $.30 per lineal foot.

*Filling of Joints.*

All joints were filled with "Prestite 77" sealing compound. This filler is a rubber-base material that is applied without heating by means of pressure equipment that fills from the bottom to the top.

All pavement was placed during the 1953 construction season. The final section was opened to traffic on November 6, 1953.

The final shaping of shoulders and backslopes will be completed during the 1954 construction season.
Fig. 12. Sawing of longitudinal center joint.

Fig. 13. Sealing a transverse joint.
FLEXIBLE PAVEMENT DESIGN

Subgrade

Although both projects have the same soil types and same general soil conditions, it was recommended that the subgrade for the flexible pavement should be compacted to a minimum density of 100 per cent of standard.

An examination of the soil profiles and CBR values for soaked specimens, compacted to 100 per cent of standard density, indicated a CBR value of approximately 5.5 as a conservative design value. Although many of the CBR test values were higher, the variation in the occurrence of soil types indicated that the most practical design dictated the selection of the lower CBR value as a basis of design for the entire contract. Following the Asphalt Institute's general practice, they selected the California Bearing Ratio design curves developed by the U. S. Army Corps of Engineers. These curves showed a preliminary combined pavement thickness of approximately 19\(\frac{1}{2}\) inches. Based on this thickness, the surcharge to be used for CBR testing should approximate 45 pounds. Checking the values previously referred to for a 45-pound surcharge, a CBR value of 5.5 was selected as satisfactory for the final design.

Fig. 14. Typical section of flexible pavement.

A check of frost penetration for this area indicated that this depth of pavement would provide sufficient cover and that frost should not materially affect the subgrade bearing capacity.

Based on CBR data, soil group index thickness criteria, as devel-
oped by the Bureau of Public Roads, and the depth of frost penetration, the Asphalt Institute recommended the following pavement section:

Item #1—One inch of asphaltic concrete surface course conforming to Indiana’s standard Type “B” AH surface as listed in section D4 of our Standard Specifications.

Item #2—One and one-half inches of asphaltic concrete AH binder course. In accordance with Indiana’s standards as listed under item #1.

Item #3—Two and one-half inches of asphaltic concrete base course. Conforming to Indiana’s standard bituminous concrete AH base as described in C4 of our Standard Specifications.

Item #4—Eight inches of water-bound macadam base course. This course to deviate from Indiana’s standard and be constructed with special equipment permitting the entire depth to be constructed in a single course.

Item #5—Free draining subbase varying from five inches in depth at the inside edge of pavement to eight inches at the outside edge. Material in this course to conform to Indiana’s Type I Subbase, with top sizes of either one and one-half inches, one inch, or one-half inch as listed under Article C1102.1 in our Standard Specifications.

SPECIAL EQUIPMENT RECOMMENDED FOR CONSTRUCTION

Included in the recommendations for the design of this pavement were two special pieces of equipment to be utilized in construction. Both of the units are relatively new and may have some influence on the future construction methods for this type of pavement. A description of the use of these units will be described under the headings of “Heavy Pneumatic Compaction Equipment” and “Multiple Shoe Vibro-Tamper.”

HEAVY PNEUMATIC COMPACTION EQUIPMENT

Highway and Airport Engineers have given much discussion and some attention to the use of super or heavy pneumatic compaction equipment, especially for flexible pavement construction, on the premise that ultimate compaction or consolidation could be obtained at the time of construction. In addition to building more structural strength into the pavements, this type of compaction may reduce or prevent “wheel track rutting,” which has in some cases been a problem for flexible type construction.

Heavy pneumatic compactors have been rather extensively used by the U. S. Army in constructing airports subjected to heavy wheel loads.
However, to our knowledge, this type of equipment has been used on only a few highway projects.

Since densities, within reasonable limits, are generally recognized as one of the major factors that affect the bearing capacity of soils, aggregates and various mixtures, it is generally desirable to obtain densities as high as practicable. Based on this premise, minimum densities for both the subgrade and the subbase were specified as 100 per cent of standard AASHO Designation T99-49.

It was also recognized that it would be desirable to have equipment with integrated loading that would produce certain specified controlled unit pressures. Such a unit could be considered as testing equipment.

The heavy pneumatic compactor was selected as a combination unit that would permit selected loadings to obtain high densities and at the same time determine with reasonable accuracy the load-supporting characteristics for the material at the time the unit was being used.

Specifications required that the compactor have a maximum gross capacity of 50 tons or 25,000 pounds per wheel.

Specifications also required that the rated maximum tire inflation pressure be not less than 90 pounds per square inch nor more than 150 pounds per square inch. The contractor was required to furnish manufacturers' charts or tabulations showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of loadings for the particular equipment furnished.

MULTIPLE SHOE VIBRO-TAMPER

A self-propelled multiple shoe vibrator was the other special piece of equipment specified. This unit was to be used as auxiliary equipment for the construction of the water-bound base course and for the compaction of the granular subbase course.

SUBGRADE REQUIREMENTS

Specifications required that the subgrade beneath and extending 18 inches on each side of the pavement surface be compacted to a depth of at least six inches to a measured density of not less than 100 per cent of maximum density as determined by AASHO specification, Designation T99-49. Where subbase material extended through the shoulder area, the subgrade was to be compacted or recompacted to at least 95 per cent of standard density.

After complying with the 100 per cent density requirement in the subgrade, the specifications required two or more complete coverages of the same area with the heavy pneumatic roller. Specifications required
that the compaction equipment be loaded and tire inflation pressures adjusted to produce a tire contact pressure as directed by the engineer.

This requirement was specified to secure a contact, or unit pressure, as nearly as practical to the maximum supporting value of the material. Complete coverage of the subgrade with this roller properly loaded would reveal any weak or soft spots that needed correction.

It was recognized that the specified densities are higher than normally required, and considerable thought was given to the possibility of encountering materials, possibly in localized areas, during wet seasons, that would have moisture contents above the optimum. In order to correct any such conditions that might be encountered, the specifications provide for aeration or removal and replacement with satisfactory material.

GRANULAR SUBBASE

Granular subbase materials were open graded, permeable sand and gravel or crushed stone. The thickness of the subbase course was variable, depending on the section used. The typical section required a depth of five inches, beginning 18 inches beyond the outside edge of the passing lane of pavement. From this point the section has a three-inch uniform fall to a point 18 inches beyond the outside edge of the traffic lane, where the thickness of the subbase is eight inches. Since the subbase material is permeable, drainage is provided. In cut sections or special cases the course is drained by a six-inch subsurface drain; however, on the major portions of the contract, drainage is provided by extending a six-inch depth of the subbase material on the same gradient through the shoulder outcropping in the fill backslope.

Placing and initial compaction of this material was in accordance with Standard Specifications. The multiple shoe vibro-tamper was used to supplement the initial compaction. After initial compaction the top two and one-half inches was scarified or loosened and approximately 70 pounds of limestone screenings added per square yard. These screenings were carefully incorporated with the loosened material by moistening and mixing and then recompacted.

The completed course was compacted to not less than 100 per cent density as specified by AASHO Designation T99-49, except the density was based on the fraction passing the three-quarter inch sieve instead of the fraction passing the #4 sieve. Any water needed as an aid to compaction was added as needed. That portion of the material extending through the shoulders beyond the paving area was placed and compacted in accordance with present requirements or 95 per cent of standard density.
WATER-BOUND MACADAM BASE

Gradation of the water-bound macadam base course was modified to permit the placing of the eight-inch course in one lay. Coarse aggregate specifications permitted Class “A” or “B” crushed stone or crushed slag, meeting the requirements of AASHO Designation M77-49, except the percentage of wear, Los Angeles test not to exceed 45 per cent. The gradation of the coarse aggregate was as follows:

<table>
<thead>
<tr>
<th>Per Cent</th>
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<tbody>
<tr>
<td>Retained on 4-inch sieve</td>
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<tr>
<td>Retained on 3(\frac{3}{4})-inch sieve</td>
</tr>
<tr>
<td>Retained on 2(\frac{1}{2})-inch sieve</td>
</tr>
<tr>
<td>Retained on 1(\frac{1}{2})-inch sieve</td>
</tr>
<tr>
<td>Retained on (\frac{3}{4})-inch sieve</td>
</tr>
</tbody>
</table>

Stone screenings to be Class “A” or “B” and meet the following gradation:

<table>
<thead>
<tr>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retained on (\frac{3}{4})-inch sieve</td>
</tr>
<tr>
<td>Retained on (\frac{3}{8})-inch sieve</td>
</tr>
<tr>
<td>Retained on No. 100 sieve</td>
</tr>
</tbody>
</table>

Screenings to form a one-inch depth of inverted choke were placed directly on the subbase, followed by the placing of the coarse stone in one lift.

Specifications required the use of a self-propelled spreading and levelling machine and a multiple shoe vibro-tamper in addition to the usual equipment.

Bituminous Courses

The two and one-half inch bituminous AH base course, the one and one-half inch AH binder course and the one-inch AH top or surface course conformed in detail to our Standard Specifications.

Specifications required the use of at least two self-powered pavers to be operated in such a manner as to obtain a monolithic or “hot” longitudinal joint.

Testing

To insure adequate control, compliance with specification requirements and to obtain complete construction data, a very detailed and complete testing program was followed. A complete field laboratory was maintained during construction. Adequate and competent personnel were provided.

Construction Contract

The contract was awarded to the low bidder, Rieth-Riley Construction Company, Goshen, Indiana. The total bid price for the entire
contract, including the bituminous resurfacing, was $922,773.34. The Engineer's Estimate was $1,003,583.72. This is a federal-aid project.

FLEXIBLE PAVEMENT CONSTRUCTION

Subgrade

As stated earlier, most of this project was pregraded.

Except for some fairly localized areas, the required 100 per cent of standard density was obtained without difficulty. At the beginning of the construction season, during the spring, some localized areas were encountered where the soils had a moisture content slightly above optimum. In these areas it was necessary to aerate the soils and reduce the moisture content sufficiently to obtain the required densities.

After the subgrade was compacted to a minimum of 100 per cent of standard density with three-wheeled ten-ton rollers the subgrade received a minimum of two complete coverages with the heavy pneumatic roller.

The gross load of the roller on the subgrade generally varied from 20 to 35 tons, producing unit pressures ranging from 50 to 70 psi.

Initial rolling with ten-ton rollers produced an average density of 103 per cent, ranging from approximately 100 to 110 per cent of standard. Final densities after two coverages with the pneumatic roller generally showed some slight increase. Coverage with the pneumatic roller disclosed a few local wet spots in the subgrade during the spring construction that required aeration and further compaction.

Subbase

Subbase material was sand and gravel obtained from a local deposit approximately one-fourth of a mile from the right-of-way near the south end of the project. A large number of control tests were run at the pit to determine compliance with gradation requirements before hauling to the grade.

Material was hauled to the grade by trucks, placed in two layers or courses, and each layer compacted with a D-8 tractor. Average gradation of the subbase material was as follows:

<table>
<thead>
<tr>
<th>Sieve sizes</th>
<th>1&quot;</th>
<th>$\frac{3}{4}$&quot;</th>
<th>$\frac{1}{2}$&quot;</th>
<th>#4</th>
<th>#8</th>
<th>#30</th>
<th>#200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total % retained</td>
<td>1.3</td>
<td>3.3</td>
<td>8.1</td>
<td>25.2</td>
<td>41.5</td>
<td>74.9</td>
<td>97.2</td>
</tr>
</tbody>
</table>

Where the subbase extended through the shoulder to provide a drainage outlet, the material was placed full width. After the subbase was compacted, the soil that was stockpiled on the inside shoulder was "clammed" across the roadway and placed on the outside shoulder.

Due to the small amount of material passing the #200 sieve, the
Fig. 15. Placing subbase material.

Fig. 16. Placing soil on the outside shoulder.
subbase lacked cohesion. This condition was anticipated and provisions made in the original design to incorporate a minimum of 20 pounds of limestone fines in the upper inch of the subbase. It was soon evident that these quantities should be increased. Approximately 70 pounds of limestone fines were incorporated per square yard in the upper two or two and one-half inches of subbase. The smaller amounts were incorporated by mixing and harrowing with spike drags. This method was discarded and a Seaman Roto-Tiller was used to incorporate the fines.

![Fig. 17. Incorporating limestone fines in the upper portion of the subbase course.](image)

After the limestone fines were incorporated in the upper portion of the subbase, the entire depth of subbase material was thoroughly wetted, then compacted with the self-propelled vibro-tamper. The back of the tamper was equipped with a wire broom. One pass with the vibrator obtained the required 100 per cent density and left a smooth, well-finished surface.

In-place densities for the subbase ranged from 100.4 per cent of standard density to 114.1 per cent. Average density was 104.9 per cent of maximum.

Although the special provisions provided for two complete coverages with the heavy pneumatic compactor, this procedure was abandoned after a few trials. The subbase material did not have sufficient cohesion
to prevent the loaded roller from displacing the material under the tires and losing the high densities obtained from previous compaction.

The contract price for subbase material, complete in place, was $3.00 per cubic yard, plus the cost of the limestone fines.

Construction of Water-bound Macadam Base

After placing 100 pounds of limestone fines to form a one-inch choke, the coarse water-bound stone was placed in one lift.

The placing of the coarse aggregate offered several problems. To obtain an eight-inch compacted course it was necessary to lay 10½ to 11 inches of loose stone. An Apsco (All-Purpose Spreader) spreader was selected for this operation. Although the spreader could place the stone satisfactorily, the subbase could be easily "torn up" by careless operation of the trucks delivering the stone to the spreader and also by the operation of the spreader. To overcome these difficulties the contractor required the loaded trucks to use a large steel plate that was pulled ahead of the spreader for entering and turning on the subbase. In addition the spreader, which operated on the inverted choke, was modified by adding an additional front wheel and equipping the drive wheels with crawler treads.
Fig. 19. Placing coarse aggregate for water-bound macadam base course.

Fig. 20. Spreader used to place coarse aggregate for water-bound macadam base.
Fig. 21. Vibrating coarse aggregate.

Fig. 22. Key-rolling coarse macadam stone.
After the coarse aggregate was placed, it was vibrated and then key-rolled with three-wheeled, ten-ton rollers.

After key-rolling, the surface was straightedged and rolled with tandem ten-ton rollers.

Following the key-rolling, fines were added and vibrated into the voids. Although there were some variations in the addition of fines, generally four applications were made. Each application was followed by a single pass of the vibrator. During the final stages of this operation, care was taken to prevent over-filling or "jacking" of the coarse aggregate.

After numerous trials it was found desirable to roll the water-bound base course with the heavy pneumatic roller at this stage of construction. Two complete coverages were made with the roller loaded to a gross weight of 35 to 50 tons, which would produce contact pressures of approximately 70 to 85 psi.

Fig. 23. Heavy pneumatic compactor loaded for rolling water-bound macadam.

It is our opinion that this method of construction produced a very good water-bound base course. A great number of inspection and test holes were dug through this base. In all cases the stone was well keyed and exceptionally well choked.

Average gradation of the stone was as follows:

Coarse Aggregate—Class "A"

<table>
<thead>
<tr>
<th>Sieve sizes (inches)</th>
<th>4&quot;</th>
<th>3½&quot;</th>
<th>2½&quot;</th>
<th>1½&quot;</th>
<th>¾&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total % retained</td>
<td>0</td>
<td>0</td>
<td>55.6</td>
<td>99.3</td>
<td>99.9</td>
</tr>
</tbody>
</table>
Fig. 24. Waterbinding macadam base.

_Stone Screenings—Class “A”_

<table>
<thead>
<tr>
<th>Sieve sizes (inches)</th>
<th>½&quot;</th>
<th>¾&quot;</th>
<th>#100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total % retained</td>
<td>0</td>
<td>0</td>
<td>76.9</td>
</tr>
</tbody>
</table>

The stone was furnished by Meshberger Stone Company, located four miles east of the intersection of State Roads #9 and #31. The stone was produced from the Jeffersonville and Geneva (dolomite) formation. The contract unit price, complete in place, was $4.35 per ton for both coarse aggregate and screenings. Although the final quantities have not been determined, the contract proposal lists a total of 35,714 tons of coarse aggregate and 22,055 tons of screenings.

**BITUMINOUS CONSTRUCTION**

All bituminous mixtures were proportioned and mixed at a central plant located near the south end of the project. The plant was a new Hetherington and Berner with hydraulic controls, mixing 5,000-pound batches.

The bituminous base course mixture consisted of #4C stone and #17 sand with 4.5 per cent bitumen. This mixture produced a very tough, stable course. Top size of the aggregate was one-inch with approximately 67 per cent retained on the #6 sieve.

The binder contained 5 per cent bitumen and produced a tough, stable mixture with approximately 65 per cent retained on the #6 sieve.
Fig. 25. Bituminous plant.

Fig. 26. Laying Type "B" surface.
Fig. 27. Pneumatic roller on the finished surface course. Roller loaded to fifty ton capacity.

Fig. 28. Plate bearing equipment.

Six and one-half per cent bitumen was used in the Type “B” surface.

The asphalt used in all three mixtures was an AP-5 (60-70 penetration). Mixes were laid at temperatures ranging from 265 to 290
degrees. Marshall tests and in-place density determinations were made on the asphallic courses.

All bituminous mixtures were laid with Barber-Green Pavers operated in a manner to form a “hot” or monolithic longitudinal joint.

Compaction was obtained with tandem and three-wheeled, ten-ton rollers.
All pavement was placed during the 1953 construction season. The final section was opened to traffic on December 11, 1953. Final shaping of shoulders and backslopes will be completed during the 1954 construction season.

TESTING AND CONSTRUCTION DATA FOR BOTH PROJECTS

As stated at the beginning of this report, a complete field laboratory was maintained on each project. Complete and detailed data were recorded during construction.

Included in the testing schedule are a series of plate loadings on each of the constructed courses.

We believe that these construction records and test data will prove invaluable in evaluating the performance of these test pavements.

TEST ROAD COMMITTEE APPOINTED

A Test Road Committee of highway engineers was appointed to make an initial cost determination, summarize test data and to initiate a future program for maintenance, testing and performance. The Committee is also charged with making an annual report on the test pavements.

The Committee is operating and definite plans and assignments have been made.

These two test pavements are well designed and constructed and will give excellent service.

The great detail involved in the original planning, design, and overall testing program, carefully followed throughout the construction, should accomplish the original intent of the program and establish many of the steps necessary in evaluating the two types of construction.