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COMMISSIONER OF HIGHWAYS

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

November 26, 1957

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

B. 3. 6.
D. 1. 7.

MEMO TO: D. V. Terrell
Director of Research

The attached report is the result of a series of experimental projects originated about a year ago by the Division of Rural Highways. Mr. Hailey requested that the Division of Research participate in the experimental designs, be on the projects during construction, evaluate the performance and prepare a report on the test installations.

A summary tabulation listing materials, quantities and costs was prepared shortly after completion of the construction, and these items are herein presented in greater detail. Approximately one year of performance data is shown primarily by means of photographs in the report.

The service life of the projects is expected to be several years, depending upon the actual use or traffic that develops. One of the projects (Webster County) was surfaced this past fall with a C-1 road mix and the soil-cement appears to be providing an excellent base for the new surface. The Ballard County bank gravel base continues to be soft and unstable, and we understand from recent reports that the District Office is considering the possibility of re-working the base and restabilizing with additional crushed stone. Continued periodic performance evaluations are programmed.

Considerable basic data on stabilization are presented in the report and should prove very useful in the design and construction of future stabilization projects.

A handwritten signature in cursive script that reads "W. B. Drake".

W. B. Drake
Associate Director of Research

WBD:dl
Enc.

Copies to: Research Committee Members
J. C. Cobb (3)

Commonwealth of Kentucky
Department of Highways

TEN RURAL HIGHWAY BASE STABILIZATION PROJECTS

by

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and

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Lexington, Kentucky

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I: Introduction

During the last week of September, 1956, the Division of Rural Highways requested assistance from the Research Division in conducting a series of ten experimental base stabilization projects which were to be geared more-or-less to a practical rural roads development program in which existing soils and local granular materials might be most advantageously treated and stabilized to provide fairly low cost base courses and surfaces, adequate for light rural traffic. The idea of actually constructing a base and bituminous surface for this type of road would represent a refinement over the traditional traffic-bound base type of construction which usually serves as a preliminary to light bituminous surfacing. While the traffic-bound type of construction has been used effectively in the past, there seems to be an inherent impatience on the part of property owners and general public to get on to the bituminous surfacing stage before the traffic-bound base has fully stabilized. In several such instances it has been necessary to add extra surfacing within a year or so, or else to revert to the traffic-bound stage again and start over.

Customarily, rural road construction involves initial grade and drain and traffic-bound surfacing. After fills and slopes have settled and stabilized, additional floater stone may be added from time to time and the roadway maintained by blading and shaping until ready for bituminous surfacing. Preparatory to surfacing, the road is sounded to determine the average depth to which the stone has penetrated and stabilized. Just prior to surfacing the loose floater is

bladed onto the shoulders or else spread uniformly over the full width and rolled. Such roads usually receive a light bituminous surfacing. A weakness in this approach arises from the fact that a large portion of the stone added is lost and is unaccountable in the measured depth of stabilized base and loose floater stone. Usually, greater depth of actually stabilized base is obtained in the wheel tracks and very little depth is obtained at the edges or between the wheel tracks. In some cases more stone may have been added during the traffic-bound stage than would have been required for the initial construction of a fairly high-type base. Further difficulties arise when the depth of traffic-stabilized base is rather optimistically estimated from soundings and the amount of traffic too conservatively estimated.

On the other hand, the construction of a stabilized base, whether initially or following a preliminary traffic-bound conditioning period, would give every assurance of uniform depth, width, and composition.

The purpose of any base, of course, is to provide a firm foundation to support the surface and the traffic loading applied to it; or, from another point of view, a base serves to interpose a layer of higher bearing-capacity material between the surface and subgrade and functions to distribute highly concentrated surface loadings over a much larger area of the weaker underlying strata. High bearing capacity or compressive strength is obtained from a more-or-less confined granular material such as crushed rock, gravel, or sand. A certain amount of confining pressure or lateral restraint is provided by the weight and friction of similar material adjacent to the loaded

area and also by the weight and rigidity of any overlying surface. This lateral and vertical confinement serves the same purpose as internal cohesion or as mortar or cement in a concretion. This is analogous to an increase in tensile strength and has the effect of enhancing the bridging qualities of the material. Various treatments imparting these qualities to a base course are simply methods of base stabilization.

In granular stabilization, one general approach is to proportion and blend the proper amount of granular material with soil so as to provide a cohesive soil mortar within the coarse aggregate structure. The granular material must provide the major structure, and transmit the major compressive loads to the subgrade. The greatest danger in this approach arises from our inability to maintain the soil mortar within the void limits of the aggregate structure and at the proper moisture content. Where there is considerable likelihood that saturation may occur, because of poor drainage or the absence of adequate surface seal, the amount of soil mortar is greatly reduced or eliminated altogether in order to provide free drainage. The water-bound macadam and dense-graded bases are all freely draining and are consequently less susceptible to saturation and to other degenerative influences, such as frost-heave. On the other hand, water-bound macadam has very little or no cohesive strength. The success of granular stabilization of soils in building base courses is highly dependent upon the control of moisture both during construction and in subsequent service. The primary use of calcium chloride in this type of stabilization is to control moisture content during construction.

The same general criteria may be applied to the use of bituminous materials to stabilize granular bases. In some respects, the bituminous materials are expected simply to waterproof the aggregate and the mortar. The amount of cohesion or cementation developed would depend largely on the type and quantity of bituminous materials used. The greatest danger in this approach is the general tendency to use too much asphalt. Excessively rich mixtures become highly lubricated, very unstable, and often may not perform as well as the untreated granular material alone. Further difficulties can arise from trying to blend bituminous stabilizing agents into a base material containing excessive amounts of fines, such as clay. Ideally, the stabilizing agent should make the mortar portion of the mixture insensitive to water and also impart some cohesive strength to the compacted base.

Soil-cement stabilization is, in effect, a means of soil solidification. It differs from the two types of stabilization mentioned above since for its use coarse granular materials may be desirable but are not essential. This method, therefore, may be particularly advantageous in areas where granular materials are not readily available; provided, of course, that the existing soil is suitable. Sandy and silty soils containing relatively small amounts of clay are easily blended and are particularly well suited to this kind of treatment. Large amounts of clay interfere with the development of strength and with durability. As a general rule the amount of cement required is high for poorly graded one-size sands devoid of silt and clay; but where silt and clay are present in significant amounts the cement requirement increases

with the percentage of silt plus clay. Soil-cement mixtures do, or should, develop a significant amount of compressive and tensile strength.

As a minimum, all of these stabilized bases require a sealing type surface to prevent infiltration of water, to present a wearing surface to traffic, and to prevent raveling of the base course itself. The surface thickness may be governed by some economic balance between the total thickness required and the optimum thickness and bearing strength of treated base material. In some cases single or double seal coats may be considered adequate, particularly if the traffic volume is expected to be relatively light or if high bearing strength is achieved in the stabilized base itself.

In this series of ten projects, the Rural Highways Division stipulated a depth of 5 in. of stabilized base for the class of roads and locations chosen for the experimental program. Either single or double seal coats were to be used for surfacing. Within these pre-set limits, it was necessary to sample and analyze the existing materials on the road to determine the availability of additional granular materials and to adjudge the most advantageous type of stabilization to be used. These preliminary surveys and quantity estimates for the individual jobs were made by the Research Division and were submitted as proposals to the Division of Rural Highways. The Research Division was further requested to observe each job and to prepare a general summary report covering the details of construction and of performance.

The work was begun October 9, and completed November 1, 1956. The projects ranged from 1 to 2 miles in length and were rather widely scattered throughout the state. The services of an S/A Trav-L-Plant, S/A Pulvi-Mixer, S/A Pneumatic Compactor, and S/A Cement

Spreader were contributed without cost by the manufacturer of the equipment. These items were hauled from one job to the next by the Department. Other equipment, such as trucks, water-wagons, and graders, was furnished by the districts in which the jobs were located. The work was programmed on such a close schedule that the S/A equipment had to be transported at night in order to start the work on the next job on schedule. Some of the jobs required the services of this equipment for only one day; some of them required two days or more. In several instances, local Highway Department maintenance crews were busy several days in advance, ditching and shaping the roadway and hauling in stone and gravel in preparation for blending and stabilization. Local maintenance crews applied the seal within a few days following the base construction. Exceptionally favorable weather prevailed throughout the fall season, and the jobs were completed according to schedule.

The projects have been observed frequently during the succeeding ten months of service, which, of course, includes the winter, spring and summer seasons. Performance on most of the projects has been generally good, although there were some adverse circumstances aside from actual base performance which reflected rather unfavorably upon the performance of the roads themselves. Fill settlement, slides, washouts, poor drainage and similar problems plagued two or three of the projects. These circumstances will be discussed in more elaborate detail in succeeding portions of this report.

II: Description of Projects

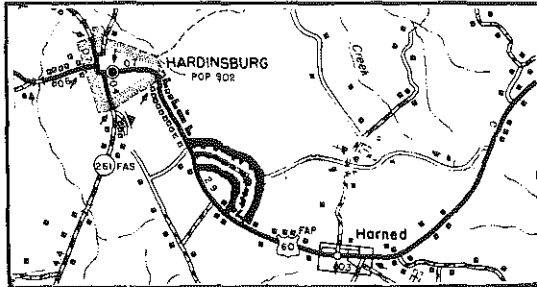
The ten projects selected by the Rural Highways Division are listed below according to the order in which they were scheduled for construction:

| <u>Date</u> | <u>County</u> | <u>Road</u> | <u>R. S. F. Project No.</u> |
|-------------|---------------|----------------------|---------------------------------|
| October 9 | Breckinridge | Fairgrounds | 14-873-1SA |
| " 11 | Webster | Providence-Lisman | 117-179-1SA |
| " 12 | Ballard | LaCenter-Hinkleville | 4-441-2SA |
| " 15 | Marshall | Beal | 79-3-1SA |
| " 17 | Barren | Oil Well | 5-952-1SA |
| " 18 | Wayne | Spann | 116-559-1SA |
| " 22 | Madison | Blue Lick | 76-791-1SA |
| " 23 | Montgomery | Welch | 87-517-1SA |
| " 24 | Lawrence | Upper Laurel Creek | 64-393-1SA |
| " 25 | Johnson | W. Van Lear | 58-917-1SA |

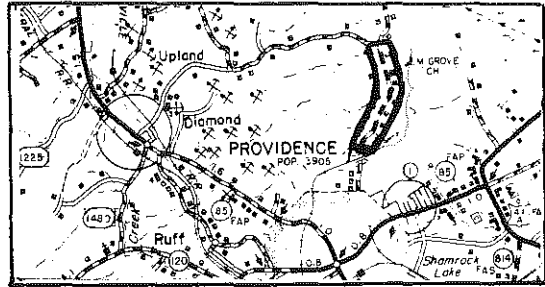
Fig. 1 serves to identify these locations graphically.

The first five projects were sounded and sampled on October 2nd and 3rd. Samples were tested immediately and estimates of quantities and types of materials required were submitted to the Director of Rural Highways. Similar proposals were made during the following week on the remaining five projects.

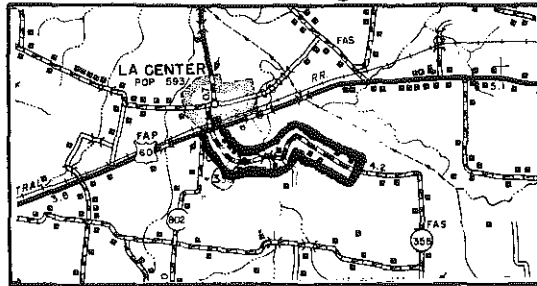
None of the roads, according to the most recent (1955) traffic data, carried more than 200 vehicles per day, except possibly a portion of the West Van Lear project. As a matter of record, traffic data are shown in the following tabulation:



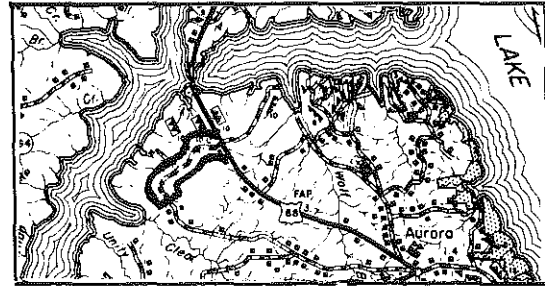
Breckinridge Co.



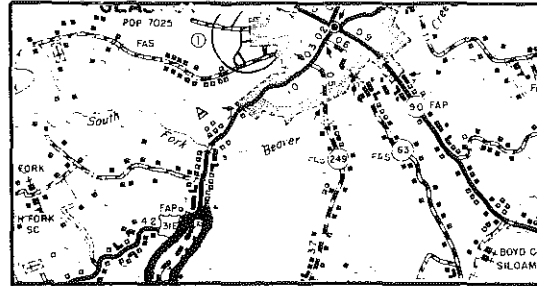
Webster Co.



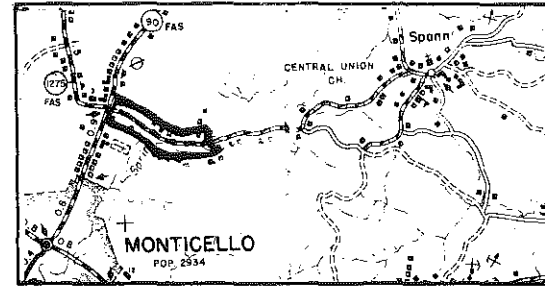
Ballard Co.



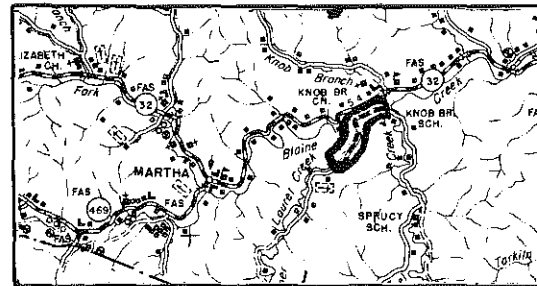
Marshall Co.



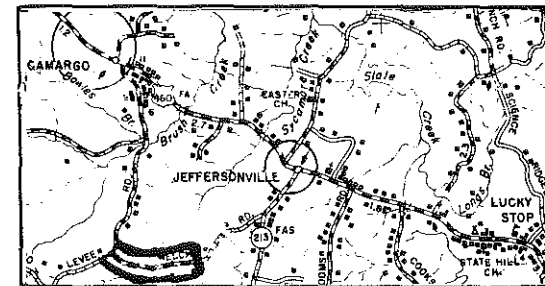
Barren Co.



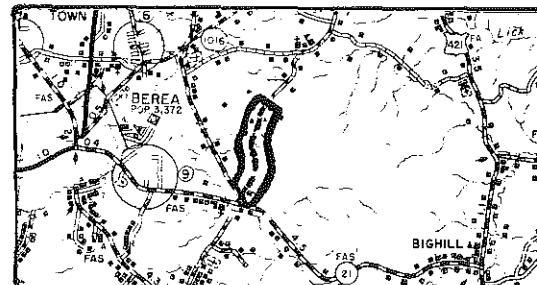
Wayne Co.



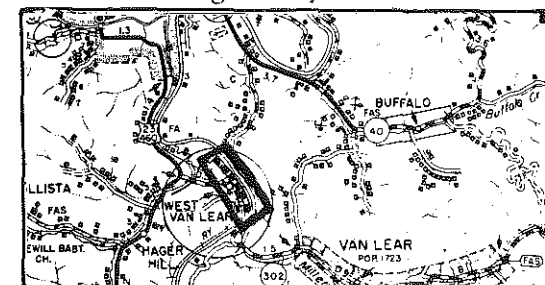
Lawrence Co.



Montgomery Co.



Madison Co.



Johnson Co.

Fig. 1: Map Sections Showing Location of Ten Rural Highway Stabilization Projects.

| <u>County</u> | <u>Traffic (1955)</u> |
|---------------|-----------------------|
| Breckinridge | No count available |
| Webster | 50 |
| Ballard | 200 |
| Marshall | 50 |
| Barren | 100 |
| Wayne | 50 |
| Madison | 135 |
| Montgomery | No count available |
| Lawrence | No count available |
| Johnson | No count available |

All of the roads were more-or-less in the traffic-bound stage except the one in Lawrence County, which had only recently been graded. Some were practically re-graded or the roadway completely renovated in order to provide a minimum width of 14 ft. of stabilized roadway; and in some cases culverts were installed and right-of-way cleared. On other projects, it was not possible to obtain the desired width and proper drainage ditches. In W. Van Lear, for instance, water and gas pipes were so close to the surface on some streets that side ditches could not be cut. In Montgomery County there was a section near the middle of the project where bedrock and shale were exposed or within a few inches of the surface. Ditches could not be excavated with a grader; and, as a consequence, the underlying shale strata have directed subsurface drainage toward the middle of the roadbed. Bedrock was exposed on a short section of the Lawrence County project, and the cuts and fills had not stabilized completely. The projects in Breckinridge, Barren, Madison and Wayne Counties all required extensive grading and ditching. Additional granular material was used on all the jobs selected for granular stabilization except the streets in W. Van Lear. Soundings there indicated an adequate thickness of existing sandstone, slag, limestone and sand.

III: Design of Stabilized Mixtures and Estimates of Quantities

Because there was not sufficient time allowed in the program, no trial mixes were made in the laboratory to pre-test any of the designs for any of the stabilizing systems proposed. Samples were gathered from each of the jobs, analyzed in the laboratory, and the most appropriate design deduced from rather limited test data. Selection of the stabilizing systems was guided to a considerable extent by the availability of materials in each area. In Ballard and Marshall Counties, for instance, the abundance of bank gravels in close proximity to the jobs virtually dictated their use. Actually these two roads already had considerable depths of fairly stable bank gravel on them. The existing depths were supplemented, of course, with fresh material, to provide the required 5 inches of stabilized base. In Lawrence County there was a scarcity of granular materials for base construction, but the existing soil appeared suitable for cement stabilization. The streets in W. Van Lear were adjudged to have an adequate depth of existing granular material, consisting largely of crushed sandstone and sand. Here bituminous treatment seemed most appropriate. Existing soils in Breckinridge and Webster Counties were adjudged suitable for cement stabilization, although various types of granular stabilization might have been equally feasible. Since there was some choice in these two cases, they were selected for cement stabilization; and the remaining four projects in Barren, Wayne, Madison, and Montgomery Counties were selected for granular stabilization, using calcium chloride to control moisture.

Data pertaining to each project are given briefly in the following:

1. BRECKINRIDGE COUNTY: 1.4 mi., 18 ft. wide

Existing soil: Silty Clay Loam (A-4-4)

Field M.C.: 8.0%

Opt. M.C.: 12.7%

L.L.: 26.4%

Max.den.: 117.8 lb./cu.ft.

P.I.: 18.2%

Sp.G.: 2.60

Soil mortar: -No. 10 = 39%; +No. 4 = 33%

Clay + silt in -No. 4 fraction: 76.1%

Granular treatment of clay pockets: 400 tons No. 610 ls.

Est. cement req. for stab.: 13% by wt. of -No. 4 soil

$13\% (100-33)/100 = 8.7\%$ by wt. of total soil

$8.7\% \times 117.8 = 10.2$ lb. cement/cu.ft.

$10.2/94 = 11\%$ cement by Vol.

$5280 \times 1.4 \times 18 \times 5/12 \times 11\%/4 = 1525$ bbl.

Est. water to be added: 3% by wt. of soil

$5280 \times 1.4 \times 18 \times 5/12 \times 118 \times .03/8.34 = 23,500$ gal.

Seal asphalt: RS-2 at .3 gal./sq.yd.

$5280 \times 1.4 \times 18/9 \times .3 = 4440$ gal.

Seal stone: No. 9 ls. at 25 lb./sq.yd.

$5280 \times 1.4 \times 18/9 \times 25/2000 = 185$ tons

2. WEBSTER COUNTY: 1 mi., 18 ft. wide

Existing soil: Silty Clay Loam

Field M.C.: 5.1%

Opt.M.C.: 14.2%

L.L.: 29.5%

Max.den.: 112.9 lb./cu.ft.

P.I.: 10.5% Sp. G.: ---

Soil mortar: -No. 10 = 77.5%; +No. 4 = 17%

Clay + silt in -No. 4 fraction: 73.6%

Granular treatment for clay pockets: 100 tons No. 9 ls.

Est. cement req. for stab.: 12% by wt. of -No. 4 soil

$12\% (100-17)/100 = 10\%$ by wt. of total soil

$10\% \times 113 = 11.3$ lb. cement/cu. ft.

$11.3/94 = 12\%$ cement by Vol.

$5280 \times 1 \times 18 \times 5/12 \times 12\%/4 = 1188$ bbl.

Est. water to be added: 5% by wt. of soil

$5280 \times 1 \times 18 \times 5/12 \times 113 \times 5\%/8.34 = 27,000$ gal.

Seal asphalt: RS-2 at .3 gal. /sq. yd.

$5280 \times 1 \times 18/9 \times .3 = 3168$ gal.

Seal stone: No. 9 ls. at 25 lb. /sq. yd.

$5280 \times 1 \times 18/9 \times 25/2000 = 132$ tons (single)

3. BALLARD COUNTY: 1.2 mi., 16 ft. wide

Existing soil: Silty Clay Loam

Field M.C.: 16% Opt. M.C.: 11.2%

L.L.: 32.8% Max. den.: 121.6 lb. /cu. ft.

P.I.: 12.0% Sp. G.: 2.69 (est.)

Combine: soil-gravel

Est. Sp. G.: 2.65 Est. Opt. M.C.: 12%

Est. max. den.: 124 lb. /cu. ft. Est. Field M.C.: 6%

Est. asphalt req.:

$124 / (2.65 \times 62.4) = 75\%$ solid Vol.

$$124 \times 12\% / 62.4 = 23.9\% \text{ liquid Vol. (max.)}$$

$$124 \times 6\% / 62.4 = 11.9\% \text{ liquid Vol.}$$

$$23.9\% - 11.9\% = 12\% \text{ max. liquid to be added (by Vol.)}$$

$$12 \times 62.4 / 124 = 6\% \text{ emulsion by wt.}$$

$$124 \times 9 \times 5 / 12 \times 6\% / 8.34 = 3.35 \text{ gal. /sq. yd.}$$

$$6\% \text{ RS-2 by wt.} \times 60\% = 3.6\% \text{ asphalt (net)}$$

$$3.35 \text{ gal.} \times 5280 \times 1.2 \times 16/9 = 37.700 \text{ gal.}$$

Add. bank gravel: (350 lb. /sq. yd.)

$$350 \times 5280 \times 1.2 \times 16/9 \div 125/27 = 1170 \text{ cu. yd.}$$

Seal asphalt: RS-2 at .3 gal. /sq. yd.

$$5280 \times 1.2 \times 16/9 \times .3 = 3380 \text{ gal. (single)} = 6760 \text{ gal. (double)}$$

Seal stone: No. 8 ls. and No. 9 ls. at 50 lb. /sq. yd.

$$5280 \times 1.2 \times 16/9 \times 50/2000 = 282 \text{ tons (double)}$$

4. MARSHALL COUNTY: 1 mi., 18 ft. wide (same design as used in Ballard County)

Existing soil: Silty Clay Loam

Field M. C.: 4.8%

Opt. M. C.: "

L. L.: 24.3%

Max. den.: "

P. I.: 4.3%

Sp. G.: "

Est. asphalt req.: 3.35 gal. /sq. yd. = 3.6% net asphalt

$$5280 \times 1 \times 18/9 \times 3.35 \text{ gal. /sq. yd.} = 35,400 \text{ gal.}$$

Add. bank gravel: (100 lb. /sq. yd.)

$$100 \times 5280 \times 1 \times 18/9 \div 125/27 = 313 \text{ cu. yd.}$$

$$313 \times 1.7 = 532 \text{ tons}$$

Seal asphalt: RS-2 at .3 gal./sq. yd.

$$5280 \times 1 \times 18/9 \times .3 = 3710 \text{ gal. (single)} = 6340 \text{ gal. (double)}$$

Seal stone: No. 8 ls. and No. 9 ls. at 50 lb./sq. yd. (double)

$$5280 \times 1 \times 18/9 \times 50/2000 = 264 \text{ tons}$$

5. BARREN COUNTY: 1 mi., 18 ft. wide

Existing T. B.: 3 in. (est.)

Subgrade soil: Silty Clay Loam

Field M. C.: 10.9%

Clay: 25%

L. L.: 31.0%

Silt + clay: 77%

P. I.: 8.9%

Soil mortar: 96%

Combine: 67% T. B. + 33% subgrade

Max. den.: 117 lb./cu. ft.

Clay: 9.2%

Opt. M. C.: 12.8%

Silt + clay: 28.5%

Combine + 40% agr. lime:

Clay: 5.5%

Silt + clay: 18.8%

Est. max. den.: 125 lb./cu. ft.

Add. agr. lime: 40% by wt. = 187 lb./sq. yd.

$$5280 \times 1 \times 18/9 \times 187/2000 = 990 \text{ tons}$$

CaCl₂: (.4%) 10 tons

Water: (5%) 30,000 gal.

Seal asphalt: RS-2 at .6 gal./sq. yd. (double)

$$5280 \times 1 \times 18/9 \times .6 = 6350 \text{ gal.}$$

Seal stone: No. 9 ls. at 50 lb./sq. yd. (double)

$$5280 \times 1 \times 18/9 \times 50/2000 = 264 \text{ tons}$$

6. WAYNE COUNTY: 1 mi., 18 ft. wide

Existing T.B.: negligible

Subgrade soil: Clay (A-6-7)

Field M.C.: 10.6%

Opt. M.C.: 18.3%

L.L.: 37%

Max. den.: 108.8 lb./cu.ft.

P.I.: 20.4%

Sp.G.: ---

Clay: 38%

Silt + clay: 65.5%

Soil mortar: 89%

Combine: 78% granular material + 22% subgrade soil

Clay in combine: 8.35%

Granular material: 50% No. 9 ls. + 50% agr. lime

Est. unit wt. of granular material: 140 lb.

Unit wt. of subgrade soil: 108 lb.

Est. unit wt. of combine: 133 lb.

Add. granular material req.:

$$133 \times .78 \times 5/12 \times 5280 \times 1 \times 18/2000 = 2050 \text{ tons}$$

No. 9 ls.: 1025 tons

Agr. lime: 1025 tons

CaCl₂: (0.4%) 10.5 tons

Water: (5%) 31,500 gal.

Seal asphalt: RS-2 at .6 gal./sq.yd.

$$5280 \times 18/9 \times .6 = 6340 \text{ gal.}$$

Seal stone: No. 9 ls. at 35 lbs./sq.yd. (double)

$$5280 \times 1 \times 18/9 \times 35/2000 = 185 \text{ tons (double)}$$

7. MADISON COUNTY: 1 mi., 15 ft. wide

Existing T.B.: negligible

Existing subgrade soil: Loam

Field M.C.: 12.6%

Opt. M.C.: 14.2%

L.L.: 29.2%

Max. den.: 112 lb./cu.ft.

P.I.: 6.7%

Sp.G.: ---

Clay: 11.5%

Silt + clay: 37.5%

Soil mortar: 59%

Combine: 32% granular material + 68% subgrade soil

Granular material: 50% No. 9 ls. + 50% agr. lime

Clay in combine: 7.8%

Est. unit wt. of combine: 124.7 lb./cu.ft.

Add. granular material req.:

$32\% \times 124.7 \times 5/12 \times 5280 \times 1 \times 15/2000 = 660$ tons

No. 9 ls. = 330 tons

Agr. lime = 330 tons

CaCl₂: (0.4%)

$52.2 \times 5280 \times 15 \times 0.4\%/2000 = 8.3$ tons

Water: (3%) 15,000 gal.

Seal asphalt: RS-2 at .5 gal./sq.yd. (double)

$5280 \times 1 \times 15/9 \times .5 = 4400$ gal.

Seal stone: No. 9 ls. at 40 lb./sq.yd. (double)

$5280 \times 1 \times 15/9 \times 40/2000 = 176$ tons

8. MONTGOMERY COUNTY: 1 mi., 14 ft. wide

Existing T.B.: negligible

Subgrade soil: Silty Clay Loam (A-4-7)

Field M.C.: 19.5%

Opt. M.C.: 15.9%

L.L.: 30.2%

Max. den.: 108.5 lb./cu.ft.

P.I.: 9.6% Sp. G.: 2.68 (est.)

Clay: 32% Silt + clay: 71%

Soil mortar: 87%

Combine: 86.7% granular material + 13.3% soil

Granular material: 40% No. 9 ls. + 60% No. 610 slag

Est. clay in combine: 4.27%

Est. unit wt. of agg. combine: 98 lb. /cu. ft.

Est. sp. g. of agg. combine: 2.41

Est. unit wt. of soil-agg. combine: 114.6/lb.

Est. sp. g. of soil-agg. combine: 2.45

Add. granular material req.:

$86.7\% \times 114.6 \times 5/12 \times 5280 \times 14/2000 = 1530 \text{ tons}$

CaCl₂: (0.4%)

$114.6 \times 5/12 \times 5280 \times 14 \times 0.4\%/2000 = 7.1 \text{ tons}$

Water: (3%)

$114.6 \times 5/12 \times 5280 \times 14 \times 3\%/8.34 = 12,700 \text{ gal.}$

Seal asphalt: RS-2 at .5 gal. /sq. yd.

$5280 \times 1 \times 14/9 \times .5 = 4107 \text{ gal.}$

Seal stone: No. 9 ls. at 35 lb. /sq. yd.

$5280 \times 1 \times 14/9 \times 35/2000 = 144 \text{ tons}$

9. LAWRENCE COUNTY: 1 mi., 14 ft. wide

Existing T.B.: none

Subgrade soil: Sandy Loam (A-2-4)

Field M.C.: 15.5%

Opt. M.C.: 13%

L.L.: 21.7%

Max. den.: 116.6 lb. /cu. ft.

P.I.: N.P. Sp.G.: 2.68 (est.)

Clay: 15% Silt + clay: 31.5%

Soil mortar: -No. 10 = 77%

Clay: -No. 4 = 18.4%

Silt + clay: -No. 4 = 38.7%

Cement req.: 9.5% by wt. of -No. 4 soil

$9.5\% (81.5)/100 = 7.74\%$ by wt. of total soil

$7.74\% \times 116.6 = 9.02$ lb. cement/cu.ft. of soil

$9.02/94 = 9.60\%$ cement by Vol.

$5280 \times 1 \times 14 \times 5/12 \times 960/4 = 740$ bbl.

Water: (3%)

$3\% \times 5280 \times 1 \times 14 \times 5/12 \times 116.6/8.34 = 13,000$ gal.

Seal asphalt: RS-2 at .4 gal. /sq. yd.

$5280 \times 1 \times 14/9 \times .4 = 3285$ gal.

Seal stone: No. 9 ls. at 35 lb. /sq. yd.

$5280 \times 1 \times 14/9 \times 35/2000 = 144$ tons

10. JOHNSON COUNTY: 2.2 mi., 16 ft. wide

Existing T.B.: 3.5 in. (est.)

Subgrade soil: non plastic

* Combine: 3-1/2 in. existing T.B. + 1-1/2 in. subgrade soil
(70% T.B. + 30% soil)

Clay in combine: 8.4%

Silt + clay in combine: 20.8%

Soil mortar: -No. 10 = 57% Opt. M.C.: 13.6%

Sp. G.: 2.65 (est.) Max. den.: 114.8 lb.

Est. asphalt for stab.: SS-1 at 6.85%

$$6.85\% \times 5280 \times 2.2 \times 16 \times 5/12 \times 114.8/8.34 = 73,000 \text{ gal.}$$

$$3.54 \text{ gal. /sq.yd.} = 4.1\% \text{ net asphalt}$$

Seal asphalt: RS-2 at .5 gal. /sq.yd.

$$5280 \times 2.2 \times 16/9 \times .5 = 10,325 \text{ gal.}$$

Seal stone: No. 9 ls at 35 lb. /sq.yd.

$$5280 \times 2.2 \times 16/9 \times 35/2000 = 361 \text{ tons}$$

IV: Construction and Performance

Most of the significant features of construction and performance are illustrated in this report by a series of photographs of each project. They show the condition of the roads before any work commenced, during stabilization, and after various periods of service.

Although the Department's maintenance crews worked several days on some of the roads, ditching, grading, hauling in stone (including installation of culvert pipe in Madison County), and otherwise preparing the road for stabilization, the blending and rolling proceeded rapidly after the crews became familiar with the operation. Early experience showed that the mixing and blending could be accomplished more easily and efficiently by scarifying immediately ahead of the pulverizing and blending equipment. In Breckinridge, Webster and Ballard Counties, only the Trav-L-Plant was used. On the remaining seven jobs both the Trav-L-Plant and a Pulvi-Mixer were used to speed up the operation. Details pertaining to each project are presented below:

1. Soil-Cement: Breckinridge, Webster and Lawrence Counties: In Breckinridge and Webster Counties, allowances were made for the use of additional granular material for treating clay pockets prior to stabilization. Cement was delivered in bulk transport trucks, transferred to dump trucks, and spread through the S/A Hercules Spreader. During mixing and blending, water was introduced from a tank truck connected to the Trav-L-Plant by a flexible 4-in. hose. The pumping and metering system on the mixer sprayed water directly into the traveling "pug". While this was accomplished in a

single pass, re-blending was sometimes necessary. The depth of blending was set at 5 inches. Following final blending, the material was compacted with the 20-ton pneumatic roller, then smoothed with a grader blade and re-rolled with a steel wheel. Seals, either single or double, were applied within two or three days. Traffic was not withheld during this short curing period before sealing. The Breckinridge County road was given a single seal, while all the remaining nine projects were double-sealed. RS-2 and RC-3 asphalts were used in Breckinridge County; MC-4 was used in Webster County; and RS-2 in Lawrence County.

In Lawrence County no allowances were made for additions of granular materials, and water was not pumped through the mixer. The roadway was sprinkled the evening before stabilization, and very little extra water was required for blending and compaction.

2. Bituminous Stabilization: Ballard, Marshall and Johnson Counties: In Ballard and Marshall Counties additional quantities of bank gravel as required to give a combined depth of 5 inches were hauled in and spread before the blending work began. The pumping system on the Trav-L-Plant was broken and was not available for direct introduction of the asphalt through the mixing pug. In these two cases the road was scarified and pulverized, and the asphalt was applied from a distributor in three or four separate passes. Each pass was gauged to deliver slightly over 1 gal. /sq. yd. This was blended into the loose base material after each application. These large quantities tended to run and pool, particularly in the wheel tracks left by the distributor; and several passes of the mixer were required to distribute and blend

the material. In these two counties, the asphalt was AE-200, a mixing-type emulsion. A portion of the emulsion originally allocated to be blended into the full 5 in. depth was actually reserved and used as a topical application on the finished base for the first seal, and RS-2 and No. 9 stone were used for the second.

In Ballard County several excessively rich spots were noticeable during mixing and rolling.

The procedure in Johnson County (W. Van Lear) differed considerably from that just described. Here no additional granular material was required. The existing material consisted of several varieties of stone, slag, and sandy soil. A large portion of the granular particles was sandstone, and some limestone and cinders were present. The stabilizing agent was SS-1 emulsion.

The roadway was first scarified, pulverized and then stabilized. Here the emulsion was introduced through the Trav-L-Plant directly from the transport truck, as shown in the series of photographs for Johnson County. Additional blending was provided by several passes of the Pulvi-Mixer. Following compaction, the base was smoothed with a patrol grader and rolled with a 10-ton steel wheel roller. After a few days of curing a double seal was applied, using RS-2 and No. 9 stone.

3. Granular Stabilization (Using CaCl_2): Barren, Wayne, Madison and Montgomery Counties: On these projects, the required quantities of granular material were added previously and spread in readiness for blending and compaction. In order to speed up the program, the roads were usually sprinkled on the eve of the day scheduled for stabilization. The roads were scarified as necessary to ease the

strain on the mixing machines. Calcium chloride was spread, the roadway watered, and the material mixed, blended and compacted. Seals were applied as soon as possible after final dressing of the compacted bases.

Performance of these roads has been influenced by local circumstances as well as by the materials used and the design of the particular stabilizing system. Of course, the purpose of the experiments in the first place was to test and evaluate these factors as well as the feasibility of using the general methods to provide low-cost all-weather rural roads. Details concerning the performance of each project are discussed below:

1. Breckinridge County - From the series of pictures, it is quite obvious that there has been a considerable loss of seal from the road. Further, it is a well recognized fact that soil-cement bases, unless adequately protected and sealed, are not in themselves sufficiently resistant to wear and weather. Loss of seal here is not considered as a failure of the base or of the seal material, but as evidence of the need for intermediate treatment and preparation of these bases for application of the seal -- that is: treatment to bond the seal properly to the base. The road was quite dry and dusty when the seal asphalt was applied, and the emulsion apparently broke before it had thoroughly penetrated the dust layer. Therefore, sufficient bond was not made with the base. If the asphalt bleeds to the surface, it sticks to tires and seal is peeled off. As a precautionary measure against recurrence of this condition, it is suggested either that the finished base be sprinkled to promote penetration of the seal asphalt (RS-2) or that the

base be treated with a diluted mixing grade emulsion and cured before application of the seal asphalt.

This job was given only a single application of seal, but similar trouble developed on the Lawrence County job, where a double seal had been used.

The road is presently in need of a bituminous seal or surface of some kind.

2. Webster County - Only 0.3 mi. of soil-cement base was completed on this job. The remaining 0.7 mi. was worked with a grader, given a treatment of CaCl_2 , compacted, and sealed. MC-4 asphalt was used for the seal. Both sections are giving satisfactory performance and can hardly be differentiated by appearance. On close inspection the section treated with CaCl_2 can be seen to have a slightly darker appearance because of retained surface moisture.

3. Ballard County - The performance of this road has not been entirely satisfactory. Several rich spots were observed during construction, and these have remained soft and unstable. While there has been very little tendency for the asphalt to bleed to the surface, some sections are deeply marked and re-marked by each passing vehicle. In some sections this continued masticating action has caused the seal to crack and check. Some of the sections are soft enough to create a noticeable drag or deceleration on an automobile. The instability is obviously in the base. The coarse gravel particles have a rather oily appearance and are not at all coated with asphalt, while the mortar portion is black and sticky with asphalt.

The road will be in need of some kind of repair in the near future, but correcting instability of this type may prove difficult. There

is some possibility, however, that the road could be scarified, re-blended with selected granular material, re-compacted, and re-sealed.

Several pertinent factors should be kept in mind in evaluating the performance of this road. In the first place, these bank gravels have always heretofore been difficult to stabilize. Secondly, the road was actually more stable (but possibly less weather-proof) in the traffic-bound condition than after the attempted stabilization. There are several possible explanations for this: either the stabilizing mixture was not properly designed (too rich) or else the addition of such bituminous material served to lubricate rather than to cement the materials together. As stated earlier, weather or moisture proofing is a matter of coating and sealing the aggregate and mortar; bearing strength is a matter of aggregate interlock, confinement and/or cementation. A seal coat offers very little vertical confinement. Therefore, all of the supporting strength must be built into the base itself. Compromising this factor in design could, in all probability, result in an improvement of water resistance without excessive lubrication of the chert gravel. While such a balanced design was not achieved in this case, it must be remembered that no optimum asphalt content was established by laboratory tests on trial mixes for any of these projects.

It is very possible that more favorable performance would have resulted if the base had been allowed to cure for a considerably longer time before compaction or application of the seal.

4. Marshall County - The materials and the design here were almost identical with those used in Ballard County, yet only two noticeably soft spots have developed, and they are of little consequence. Both this road and the one in Ballard County contain approximately 3.6% net

asphalt content (6% AE-200). However, a difference in wear on the seal coats is quite apparent, suggesting a rather large difference in the volume of traffic using the two roads. This road is apparently in very good condition.

5. Barren County - Performance here has been very good. Some maintenance has been performed on the seal, but the base seems quite stable, and the road is in excellent condition.

6. Wayne County - About a quarter of a mile of this road was badly washed during the flash flood (see photographs), and part of the seal and base were lost. A little skin patching has been done elsewhere, and the remainder of the road is in very good condition.

7. Madison County - General performance here has not been quite as good as it has in Barren County. There has been some consolidation or deformation in the wheel tracks, several small pot-holes have developed, and in one sharp curve most of the seal and base have been raveled away. At two locations where culverts were installed, water has overrun the fills and caused some damage. Some repairs have been made there and a few of the pot-holes have been patched (see recent photographs). Logging trucks are known to have used the road, and this may account for most of the deformation, since the road was not designed for very heavy wheel loads.

8. Montgomery County - Several prominent failures have developed here; but, as mentioned earlier, the cause is attributable to sub-base conditions rather than to the base itself. Shale outcroppings at several places along the sloping grades not only prevent subsurface drainage of the base but concentrate subsurface water at these points.

Saturation has therefore weakened the base and caused failure. Sections of the road both above and below the outcroppings have shown fair to good performance.

9. Lawrence County - This road had only recently been graded and actually was not ready for stabilization treatment. Fills were too narrow in some places, and bedrock was exposed in others. These factors, of course, are reflected in the performance. In those sections where the subgrade was satisfactory, the soil cement base has performed rather well. However, as shown by the photographic record, there has been a tendency for the seal to strip off here as it did in Breckinridge County. Early in the spring of 1957, during the rainy period, a part of the road was flooded. Side ditches filled up, soil and debris were washed onto the road, mud-holes developed, and some sections failed badly. None of the photographs show the road at its worst condition. During the summer, traffic has smoothed and re-compacted most of those places.

10. Johnson County - It should be pointed out that most of these streets were fairly stable and serviceable before the stabilization treatment. The traffic-bound stone was not well graded and tended to ravel and develop pot-holes. Most of the streets had no side ditches, and it was not possible to cut any because of utility pipes. Yet, aside from several recurrences of pot-holes and considerable wear on the seal coat at corners, performance has been generally good. The existing base material was porous and sandy, and even though the net asphalt content approximates 4.1%, there has been no indication of instability similar to that observed in Ballard County. The more heavily traveled streets need some patching and sealing. It should be noted

that all of the asphalt on this project was applied through the pump and spray bar of the Trav-L-Plant. A uniform distribution and blend were obtained before the base was compacted.

V: Materials and Costs Summaries

Table I shows the quantity and type of materials used for each of the ten jobs. Table II shows the itemized costs, computed costs per square yard of road, and the approximate total costs for each job.

Bank gravels for Ballard and Marshall Counties were purchased on a royalty basis and hauled by the Department. Aggregates for Barren, Wayne, and Montgomery Counties were delivered by the supplier but were hauled to the Madison County job by the Department. These factors, of course, are apparent in the itemized costs of materials, labor, and rental of equipment. Portland cement and emulsified asphalts were also delivered by the supplier.

Neither the costs summary nor the computed costs per square yard include any charges for the services of the Seaman-Andwall equipment except the expense to the Department for transporting it from one job to the next. Some allowance for this would have to be included in the computations in order to derive a more realistic cost per square yard for the various types of stabilization. Cost data for Webster County may be rather misleading because only 0.3 mi. of the road was completed and some of the charges included probably applied to the remaining 0.7 mi., which was given a different kind of treatment.

Some discrepancies in the total charges to the projects exist between the tabulations of disbursements (Form MR-2) and the cost summaries supplied by the respective Districts. The large discrepancy for Barren County arises from the fact that Form MR-2 did not include the cost of 8.7 tons of CaCl_2 or the cost of 7812 gal. of RS-2.

TABLE I
MATERIALS SUMMARY

| Type of Stabilization | Granular Stab. With AE-200 or SS-1 | | | Granular Stab. (with CaCl ₂) | | | | Soil Cement Stab. | | |
|--------------------------|---------------------------------------|---------------------------|-----------------|--|------------------|---------------|------------------------|--------------------|-------------------------|---------------------------|
| County | Ballard | Johnson | Marshall | Barren | Madison | Montgomery | Wayne | Breckinridge | Lawrence | Webster |
| Road | LaCenter - Hinkleville Rd. | Streets in W. Van Lear | Beal Rd. | Oil Well Rd. | Blue Lick Rd. | Welch Rd. | Beech H.- Spann Rd. | Fairgrounds Rd. | Upper Laurel Cr. Rd. | Providence- Lisman Rd. |
| R.S.F. No. | 4-441-2SA | 58-917-1SA | 79-3-1SA | 5-952-1SA | 76-791-1SA | 87-517-1SA | 116-559-1SA | 14-873-1SA | 64-393-1SA | 117-179-1SA |
| Length of Project | 1.2 mi. | 2.2 mi. | 1 mi. | 1 mi. | 1 mi. | 1 mi. | 1 mi. | 1.4 mi. | 1 mi. | 0.3 mi.* |
| Approximate Width | 16 ft. | 16 ft. | 18 ft. | 18 ft. | 15 ft. | 14 ft. | 18 ft. | 18 ft. | 14 ft. | 18 ft. |
| Depth | Variable | 5 in. | Variable | 5 in. | 5 in. | Variable | 5 in. | 5 in. | Variable | 5 in. |
| Materials for Stab. | | | | | | | | | | |
| AE-200 (gal.) | 31424 | -- | 27092 | -- | -- | -- | -- | -- | -- | -- |
| SS-1 (gal.) | -- | 73009 | -- | -- | -- | -- | -- | -- | -- | -- |
| P. Cem. (bbl.) | -- | -- | -- | 8.7 | 8.5 | 7.1 | 10.0 | 1547 | 766 | 453 |
| CaCl ₂ (tons) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Bank Gr. (cu. yd.) | 1154 | -- | 538 | -- | -- | -- | -- | -- | -- | -- |
| Crushed Sla (tons) | -- | -- | -- | -- | -- | 902 (#610) | -- | -- | -- | -- |
| Crushed Limestone (tons) | -- | -- | -- | 1012 (#9) | 330 (#9) | .617 (#11) | 1194 (#9) | 400 (#610) | -- | 100 (#9) |
| | | | | | 330 (#9) | | 1012 (#9) | | | |
| Materials for Seal | | | | | | | | | | |
| AE-200 (gal.) | 3380 | -- | 3168 | -- | -- | -- | -- | -- | -- | -- |
| RS-2 (gal.) | 3164 | 9918 | 2992 | 7812 | 4517 | 4084 | 5917 | 3163 | 3159 | -- |
| MC-4 (gal.) | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1904 |
| RC-3 (gal.) | -- | -- | -- | -- | -- | -- | -- | 1300 | -- | -- |
| Chips (tons) | 280 (#8, #9) | 345 (#9) | 266 (#8, #9) | 256 (#9) | 176 (#9) | 140 (#9) | 182 (#9) | 190 (#9) | 144 (#9) | 58 (#9) |

* Not completed in time scheduled. Remaining 0.7 mi. received topical application of CaCl₂ and then sealed.

TABLE 2
COSTS SUMMARY

| Type of Stabilization | Granular Stab. with AR-200 or SS-1. | | | Granular Stab. (with CaCl ₂) | | | | Soil Cement Stab. | | | |
|--------------------------------------|--|---------------------------|------------|--|------------------|------------|------------------------|--------------------|-------------------------|----------------------------|-------------|
| County | Ballard | Johnson | Marshall | Barren | Madison | Montgomery | Wayne | Breckinridge | Lawrence | Webster | Total |
| Road | LaCenter - Pinkleville Rd. | Streets in W. Van Lear | Beal Rd. | Oil Well Rd. | Elus Lick Rd. | Welch Rd. | Beech E.- Spenn Rd. | Fairgrounds Rd. | Upper Laurel Cr. Rd. | Providence - Lisman Rd. | |
| R.S.F. No. | 4-441-2SA | 58-917-1SA | 79-3-1SA | 5-952-1SA | 76-791-1SA | 87-517-1SA | 116-549-1SA | 14-873-1SA | 64-393-1SA | 117-179-1SA | |
| Length of Project | 1.2 mi. | 2.2 mi. | 1 mi. | 1 mi. | 1 mi. | 1 mi. | 1 mi. | 1.4 mi. | 1 mi. | 0.3 mi. * | |
| Approximate Width | 16 ft. | 16 ft. | 18 ft. | 18 ft. | 15 ft. | 14 ft. | 18 ft. | 18 ft. | 14 ft. | 18 ft. | |
| Depth | Variable | 5 in. | Variable | 5 in. | 5 in. | Variable | 5 in. | 5 in. | Variable | 5 in. | |
| Cost of Preparation for Stab. | | | | | | | | | | | |
| Labor | \$261.13 | \$279.78 | \$170.98 | \$417.60 | \$282.60 | \$1413.87 | \$464.61 | \$644.95 | \$287.87 | \$144.76 | |
| Equipment Rental | 600.25 | 71.59 | 94.85 | 393.93 | 1351.37 | 693.44 | 239.89 | 653.12 | 163.28 | 145.40 | |
| Materials | | | | | | | | | | | |
| Drainage Pipe | | | | | 1183.92 | | | | | | |
| Sub. Total | 861.38 | 351.37 | 265.83 | 811.53 | 2817.89 | 2107.31 | 704.50 | 1308.07 | 451.15 | 290.16 | \$9,969.19 |
| Cost of Stab. | | | | | | | | | | | |
| Labor | 1020.58 | 1566.93 | 1345.11 | 945.44 | 2373.75 | 530.28 | 512.15 | 1237.15 | 890.10 | 554.30 | |
| Equipment Rental | 678.25 | 1039.01 | 1266.30 | 1221.11 | 3237.30 | 1373.28 | 992.38 | 859.75 | 629.97 | 541.07 | |
| Materials for Stab. | | | | | | | | | | | |
| Asphalt Em. AR-200 | 4069.41 | | 3003.11 | | | | | | | | |
| Asphalt Em. SS-1 | | 9436.19 | | | | | | | | | |
| P. Cem. (Std.) | | | | | | | | 5445.44 | 2964.77 | 1739.52 | |
| Calcium Chloride | | | | 396.72 | 328.70 | 264.12 | 405.71 | | | | |
| Bank Gravel | 57.50 | | 26.90 | | | | | | | | |
| Crushed Slag | | | | 2530.00 | 561.00 | 3721.55 | 3795.00 | 540.00 | | 215.00 | |
| Crushed Limestone | | | | | | | | | | | |
| Sub. Total | 5825.74 | 12,062.13 | 5641.42 | 5093.27 | 6500.75 | 5889.21 | 5710.24 | 8,082.34 | 4,484.84 | 3049.89 | 62,339.83 |
| Cost Per Sq. Yd. | .518 | .585 | .534 | .482 | .738 | .715 | .542 | .546 | .546 | .965 | |
| Cost of Materials for Seal | | | | | | | | | | | |
| AR-200 | 437.71 | | 394.73 | | | | | | | | |
| BS-2 | 409.74 | 1286.36 | 372.80 | 1113.21 | 598.50 | 546.03 | 846.72 | 417.83 | 437.84 | 231.34 | |
| MC-4 | | | | | | | | 158.99 | | | |
| EC-3 | | | | | | | | 240.00 | 554.40 | 106.72 | |
| Chips | 711.96 | 1380.00 | 444.38 | 450.59 | 149.60 | 315.00 | 364.40 | | | | |
| Sub. Total | 1559.41 | 2666.36 | 1211.91 | 1563.80 | 748.10 | 861.03 | 1211.12 | 816.82 | 992.24 | 338.06 | 11,968.85 |
| Total | 8246.53 | 15,079.86 | 7119.16 | 7468.60 | 10,066.74 | 8,897.55 | 7,625.86 | 10,207.23 | 5928.23 | 3678.11 | 84,277.87 |
| Engineering And Adm. (5%) | 412.33 | 753.99 | 355.96 | 373.43 | 503.34 | 442.88 | 381.29 | 510.36 | 296.41 | 183.90 | 4213.89 |
| Grand Total | \$8,658.86 | \$15,833.85 | \$7,475.12 | \$7,842.03 | \$10,570.08 | \$9,300.43 | \$8,007.15 | \$10,717.59 | \$6,224.64 | \$3862.01 | \$88,491.76 |
| General Ledger (Form MR-2) | 8,105.00 | 16,374.92 | 7,055.73 | 5,923.96** | 9,302.92 | 8,737.39 | 7,473.34 | 10,165.32 | 6,558.29 | 3708.75 | |
| Total Cost Per Sq. Yd.*** | .769 | .795 | .709 | .743 | 1.20 | 1.13 | .758 | .727 | .800 | 1.22 | |

* Not completed in time scheduled. Remaining 0.7 mi. received topical application of CaCl₂ and then sealed.

** Ledger total for Barren County does not include cost of CaCl₂ and BS-2.

*** Computed from largest total.

Note: Costs for services of S/A equipment not included in tabulation and computations.

VI: Further Considerations

Stabilized bases for roads of this type may demand more inherent bearing and cohesive strength than bases for higher types of roads, which are overlain by greater thicknesses of pavement. While some stabilizing methods may provide the desired waterproofness and durability, they may be incapable of giving the necessary bearing strength. Thus, strength and stability tests on trial mixes offer a fairly good criterion for judging the improvement derived from the use of varying amounts of stabilizing admixtures and thereby furnish valuable information about the mechanical and economic feasibility of constructing such a base. Undoubtedly there are cases where conditions are such that stabilization should not be attempted. For instance, stabilization should never be used as a substitute for proper drainage, nor should a stabilized base of this type be expected to serve under traffic conditions normally requiring a high-type pavement.

Selection of a stabilizing system should be naturally guided by the characteristics of the existing soils, availability and cost of local granular materials, delivery cost of admixtures, and comparative tests on trial mixes. While each individual case should be thoroughly evaluated, actual experience with general types of materials and methods is needed to establish reliability and proper design criteria. Western Kentucky bank gravels, for instance, have usually been treated with bituminous materials or calcium chloride in attempted stabilizations. These gravels are characteristically rounded and glassy and develop very little inter-particle friction or interlock.

Therefore, stabilization for these materials should be designed to provide appreciable confinement and cementation. Perhaps portland cement, lime or lime and fly ash might be used more successfully. Eastern Kentucky sandstones offer other promising possibilities for base construction. These aggregates characteristically develop high inter-particle friction and are not so susceptible to lubrication by treatment with bituminous materials. Proper attention to design may reduce the quantities of admixture required for stabilization.

A study devoted to lime-fly ash stabilization of soil is now in progress in the Research Laboratory. This work probably will be carried further as time permits; and eventually it may include some of the possible variations just mentioned.

The real economy in this type of construction is derived from the use of a base consisting largely of existing or local materials adequately stabilized and in combination with light seal-type bituminous surfacing. Deficiencies in strength of some difficultly stabilized bases could be compensated, of course, by the use of a heavy bituminous surface over them; but this could more than double the cost per mile for this type of road, and the desired economic objectives would not be achieved. These comments, of course, are intended to emphasize further the importance of strength in the base if it is expected to serve without the benefit of a significant thickness of surface.

APPENDIX

Photographic Record of Projects



Fig. 2: Breckinridge Co.: Fairgrounds Road before Stabilization, Looking East. (10-2-56)



Fig. 3: Breckinridge Co.: Same Road as above before Stabilization, Looking West. Note markedly different condition of original surface. (Before 10-2-56)



Fig. 4: Breckinridge Co.: Spreading Cement, after Ditching, Grading, and Scarifying. (10-9-56)

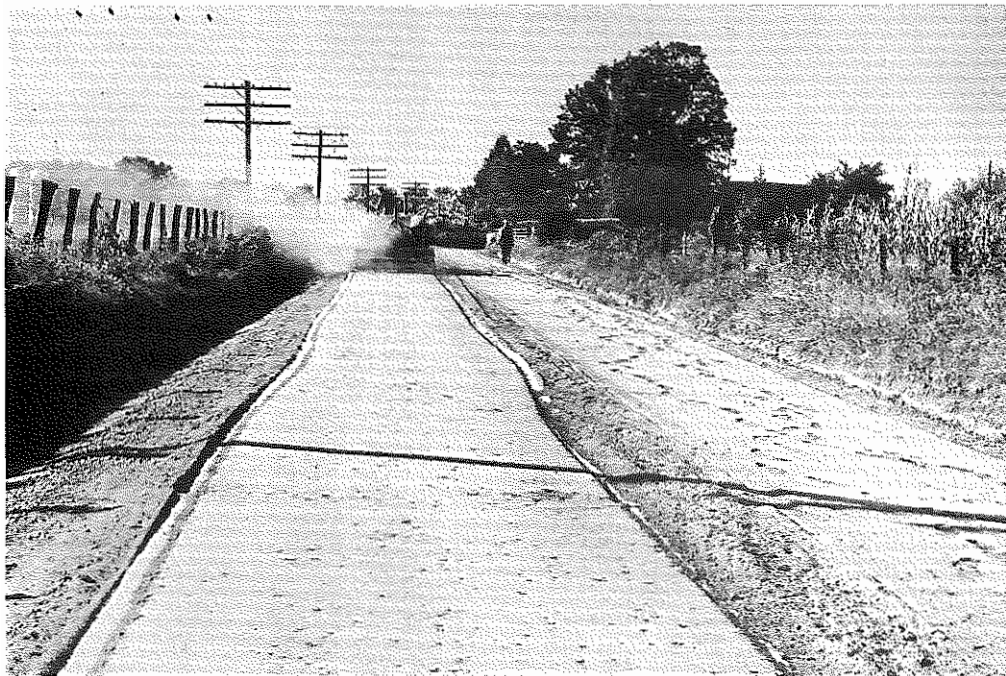


Fig. 5: Breckinridge Co.: Blending Cement and Soil with Seaman Trav-L-Plant. Mixer processes 7-ft. strip. (10-9-56)



Fig. 6: Breckinridge Co.: Curve at Middle of Project, after Sealing. Arrows point to spots where single seal failed to stick. (10-17-56)



Fig. 7: Breckinridge Co.: Same Section of Road Shown in Fig. 3, after Application of Single Seal Coat. Arrow indicates a soft spot, kept saturated by pond in field to left.

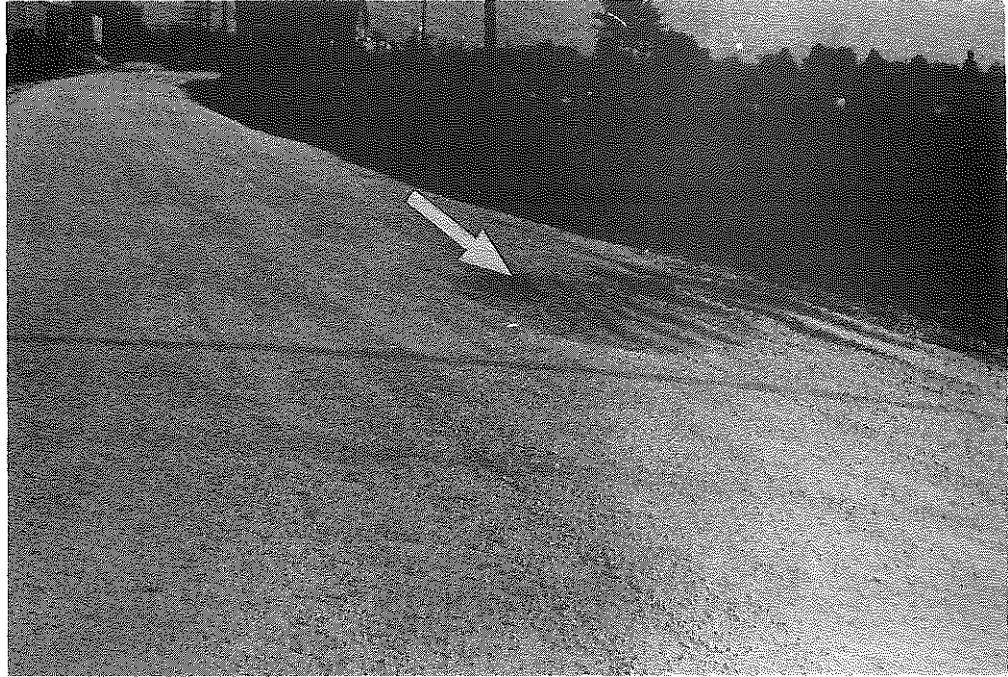


Fig. 8: Breckinridge Co.: Same Spot Shown in Previous Figure. (10-17-56)



Fig. 9: Breckinridge Co.: General Condition of Road after about 2-1/2 Months. Failure of seal coat to stick is attributed to absence of prime. (1-3-57)



Fig. 10: Breckinridge Co.: Failure of Seal. Soil cement should probably have been primed with diluted emulsion and cured before applying seal. (1-3-57)



Fig. 11: Breckinridge Co.: General Condition of Seal after about 7 Months. (4-24-57)

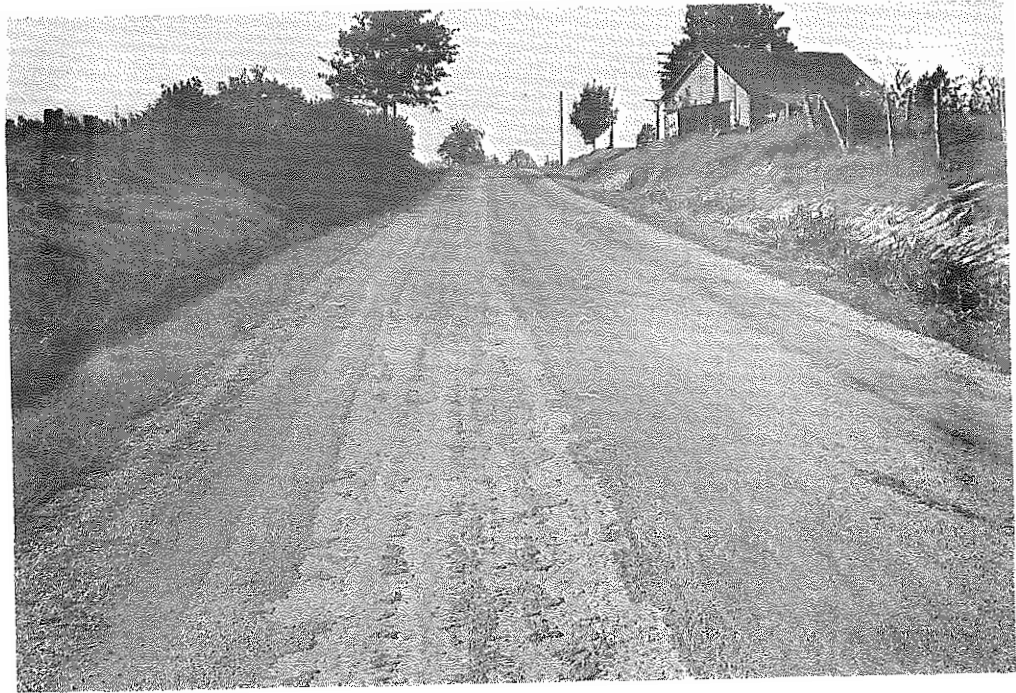


Fig. 12: Breckinridge Co.: After 10 Months. (8-4-57)



Fig. 13: Breckinridge Co.: Same Road as above, Different View, after 10 Months. (8-4-57)



Fig. 14: Webster Co. : Portion of 0.3 mi. Section of Project Where Soil-Cement was Used. The remaining 0.7 mi. was not completed in the time scheduled. (4-24-57)

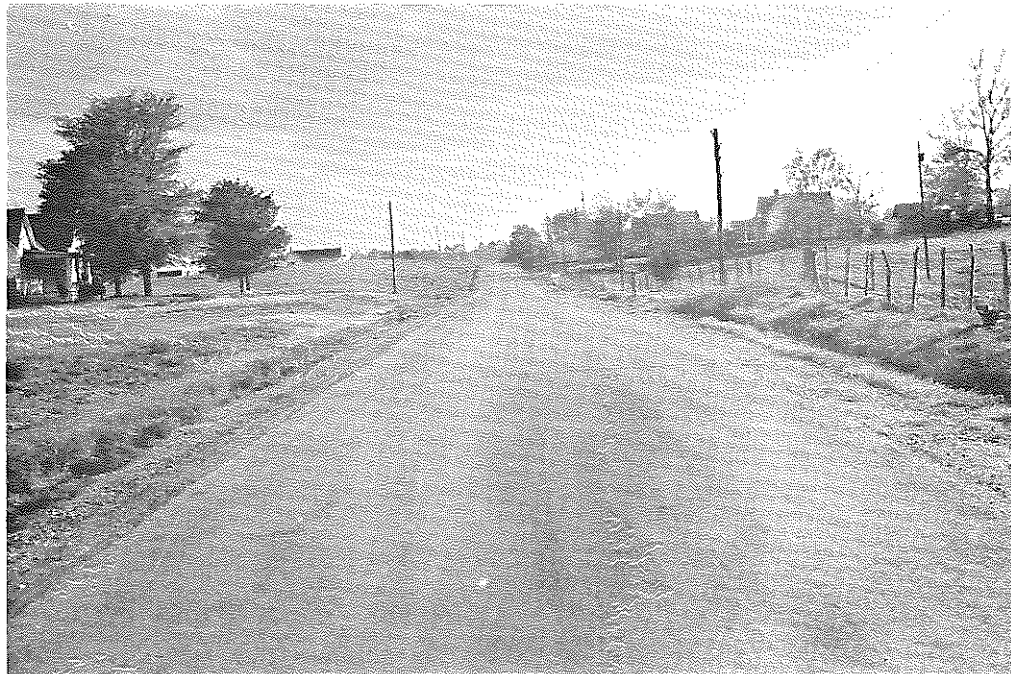
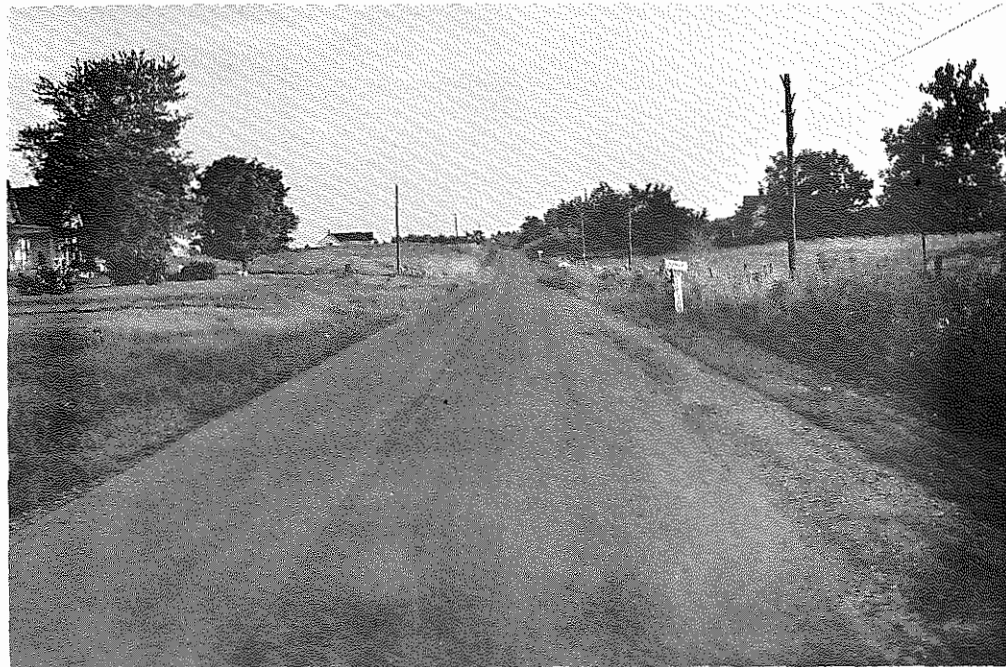


Fig. 15: Webster Co.: Remaining 0.7 mi., Re-compacted as a Granular Base, Given a Topical Application of CaCl_2 , and the Same Seal Applied. At the time the photo was made this section could not be differentiated in appearance from the soil-cement section. (4-24-57)



**Fig. 16: Webster Co.: Soil-Cement Section after 10 Months.
(8-4-57)**



**Fig. 17: Webster Co.: Calcium Chloride Treated Section after
10 Months. (8-4-57)**



Fig. 18: Ballard Co.: Scarifying ahead of the Traveling Mixer. This facilitated the mixing and blending operation. (10-12-56)



Fig. 19: Ballard Co.: AE-200 Being Applied with a Distributor Just Ahead of the Traveling Mixer. Three such applications were necessary to obtain the required asphalt content. (10-12-56)



Fig. 20: Ballard Co.: Traveling Mixer, Designed to Spray the Proper Amount of Asphalt Directly from Distributor into the Mixing Pug in a Single Pass. Pump was not operating during this project, however, and several passes with the distributor were necessary for application and blending. (10-12-56)



Fig. 21: Ballard Co.: Pneumatic Roller Making First Pass After Final Blending. Following compaction, the base was bladed smooth and finished with a steel flat-wheel roller. (10-12-56)



Fig. 22: Ballard Co.: Close-up of AE-200 - Bank Gravel Base after First Pass of Pneumatic Roller. (10-12-56)



Fig. 23: Ballard Co.: Applying Second Seal. (10-18-56)



Fig. 24: Ballard Co.: General Appearance of Road after 2-1/2 Months. (1-3-57)



Fig. 25: Ballard Co.: General Appearance after about 7 Months. Dark spots in road are due to early morning dew. (4-24-57)



Fig. 26: Ballard Co.: Dark Mottling Resulting from a Tendency of the Seal Asphalt to Bleed. Seal is badly cracked from instability and movement within the base. (8-4-57)



Fig. 27: Ballard Co.: Section Showing Rutting and Shoving although Seal has not yet Broken. Section appeared excessively rich during construction. Note: Bridge is being replaced with one of pre-cast type. (8-4-57)

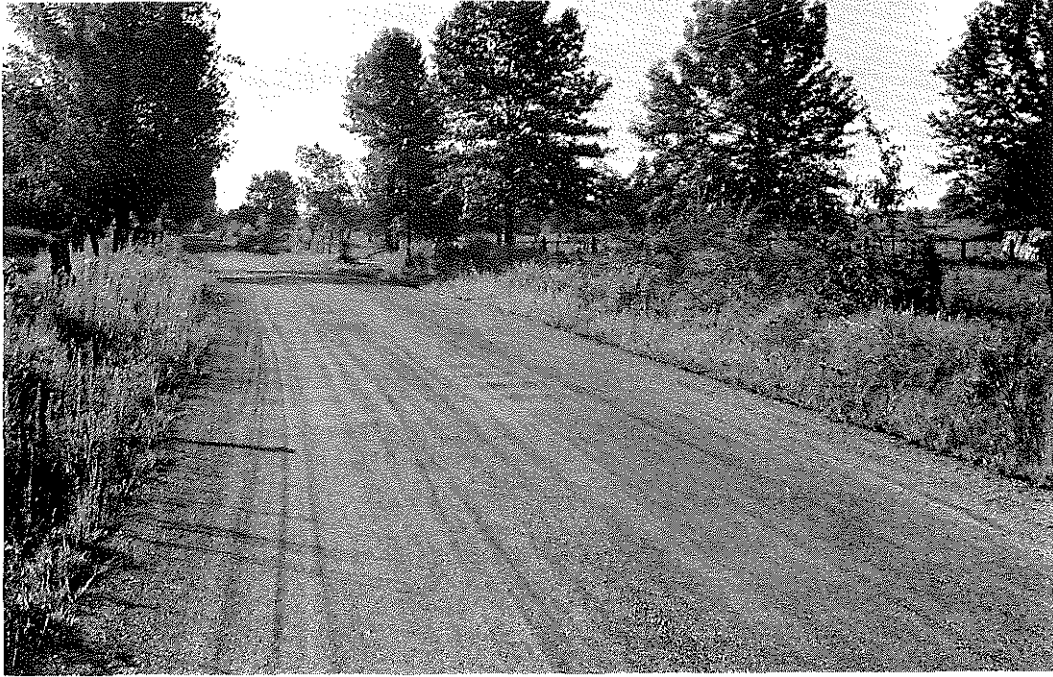


Fig. 28: Ballard Co.: Section Showing Rutting and Some Shoving. Seal here is not broken but base is soft and easily deformed. Each passing vehicle re-marks the road. Failure is impending throughout most of the length of the project. (8-4-57)



Fig. 29: Marshall Co.: After Stabilizing, before Flat-Wheel Rolling Preparatory to Sealing. (10-18-56)



Fig. 30: Marshall Co.: After Flat-Wheel Rolling before Sealing. Photo was taken toward US 68. (10-18-56)

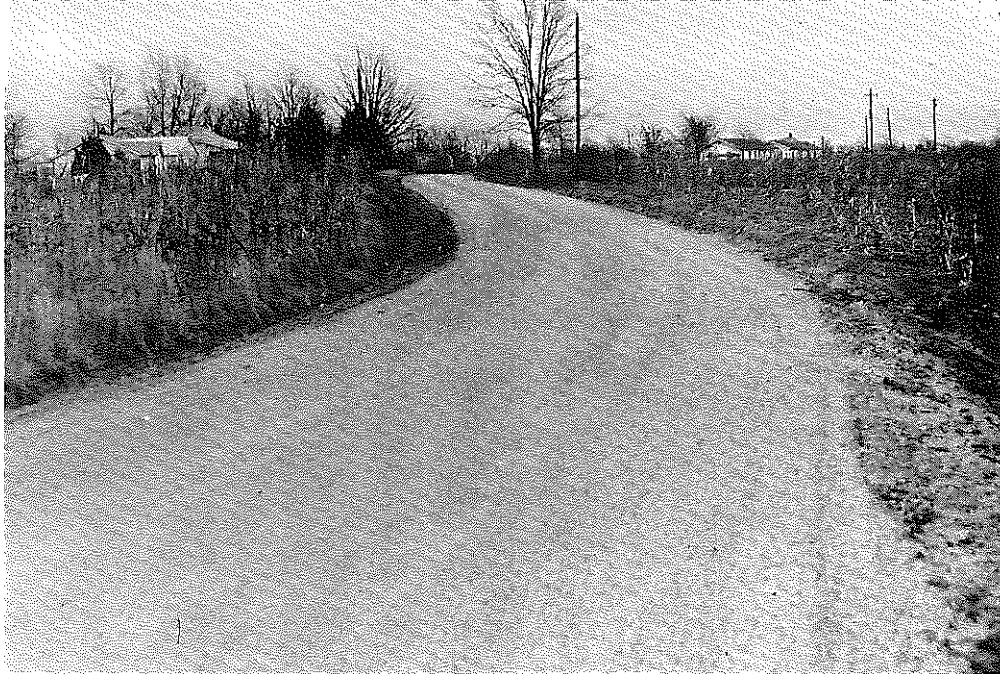


Fig. 31: Marshall Co.: General Appearance after 2-1/2 Months. (1-3-57)

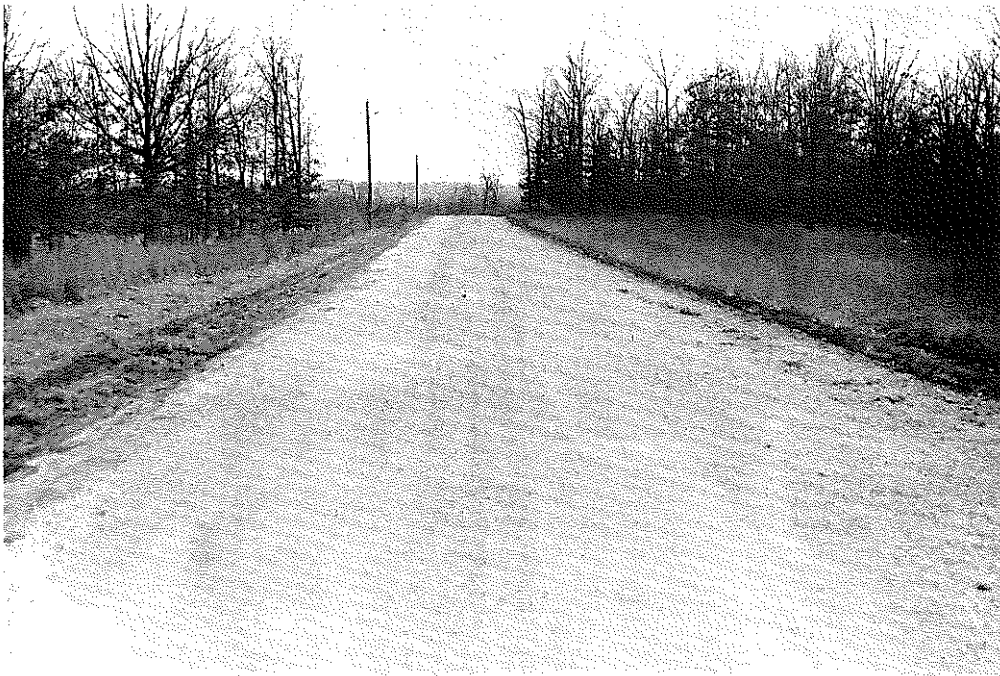


Fig. 32: Marshall Co.: Section Similar to the Above. (1-3-57)



Fig. 33: Marshall Co.: Seven Months after Stabilization. General performance and appearance have been good. Note gravel pit immediately to the right of roadway. (4-24-57)



Fig. 34: Marshall Co.: Same View as Above, after 10 Months. (8-4-57)

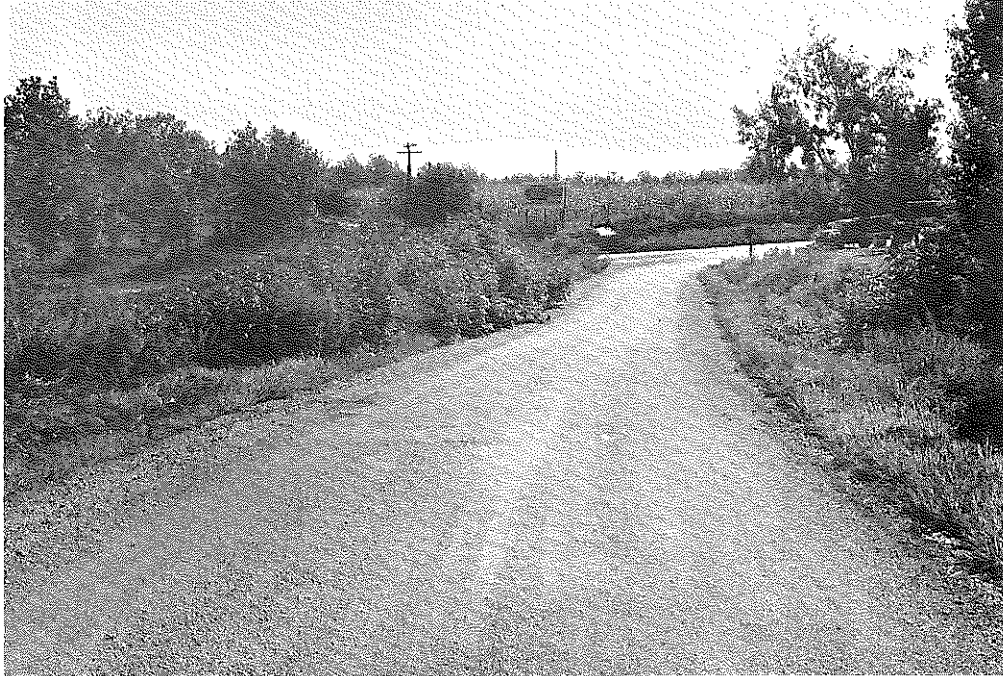


Fig. 35: Marshall Co.: Looking toward US 68, after 10 Months. (8-4-57)



Fig. 36: Marshall Co.: Middle Section of Project after 10 Months. (8-4-57)



Fig. 37: Barren Co.: Typical Appearance before Stabilization Work Began.



Fig. 38: Barren Co.: Appearance after 2-1/2 Months. (1-3-57)



Fig. 39: Barren Co.: Similar Section after 2-1/2 Months. (1-3-57)



Fig. 40: Barren Co.: Similar Section after 7 Months. (4-24-57)

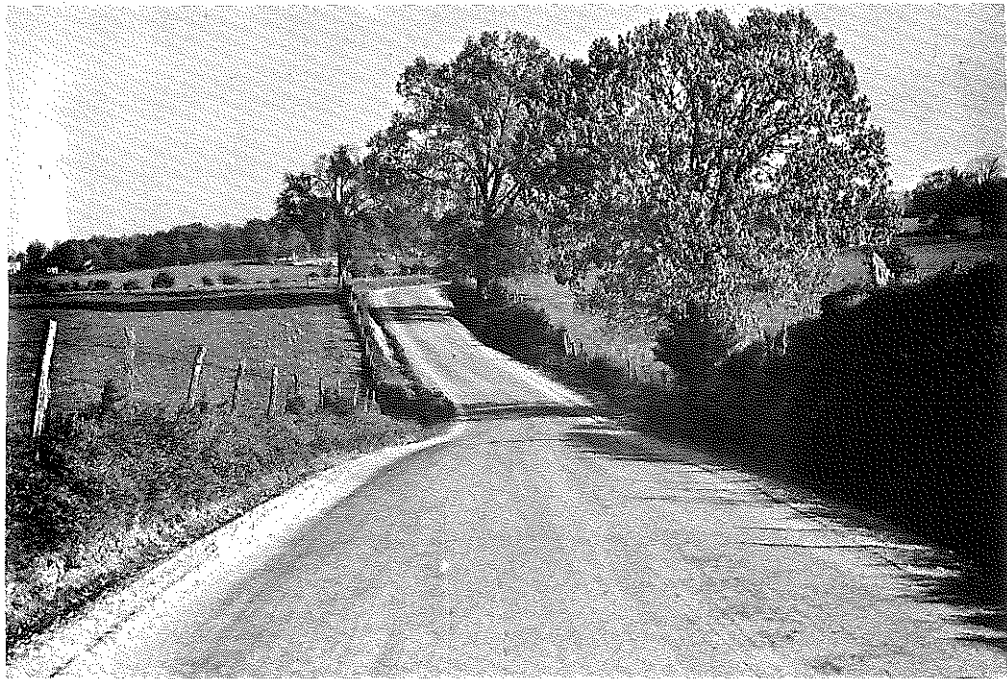


Fig. 41: Barren Co.: Similar Section after 7 Months. (4-24-57)



Fig. 42: Barren Co.: After 10 Months. (8-5-57)



Fig. 43: Barren Co.: After 10 Months. (8-5-57)



Fig. 44: Wayne Co.: Typical Section after 2-1/2 Months. Granular stabilized soil, CaCl_2 , double seal. (1-3-57)

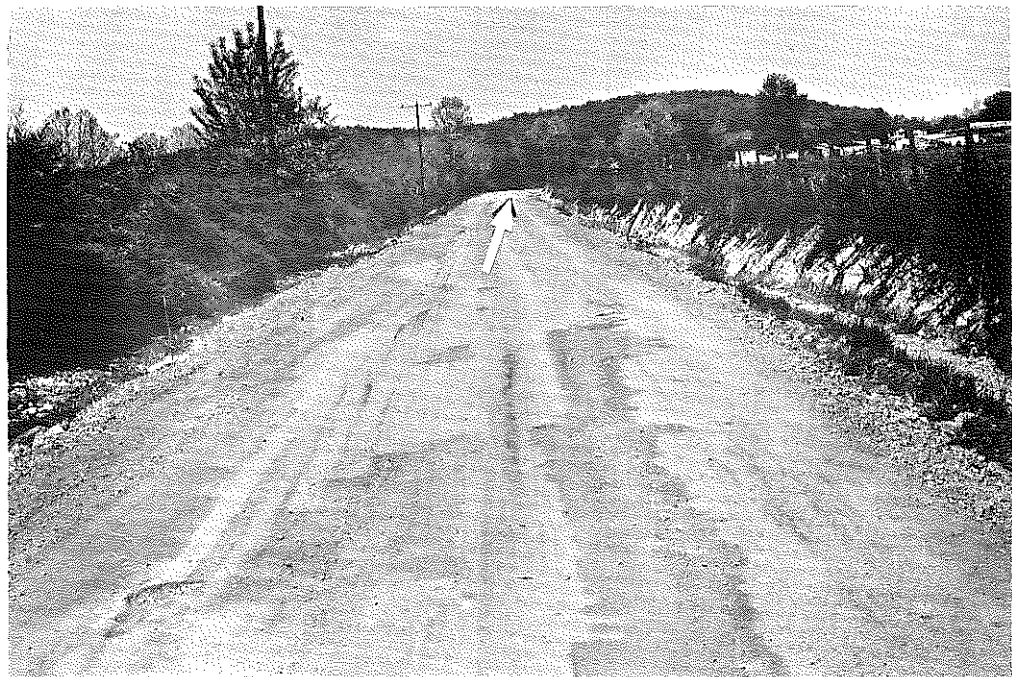


Fig. 45: Wayne Co.: After 7 Months. This section was flooded and eroded during spring rainy season. Arrow indicates one end of flood damaged section. (4-24-57)



Fig. 46: Wayne Co.: Typical Section after 7 Months. Note patching. (4-24-57)

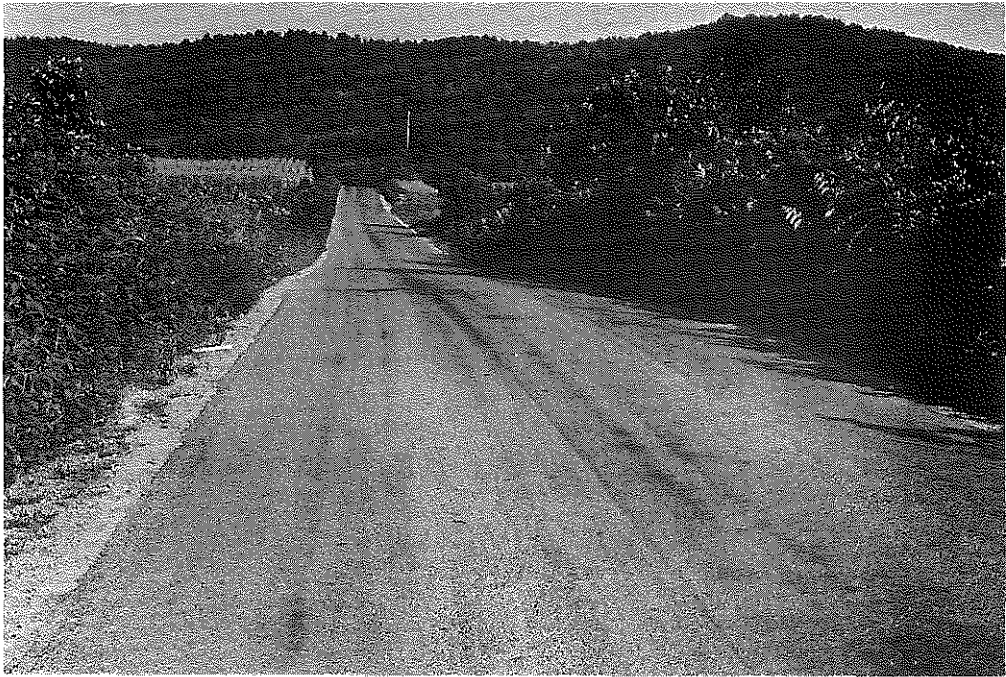


Fig. 47: Wayne Co.: One of the Better Sections, after 10 Months. (8-5-57)



Fig. 48: Wayne Co.: Section Affected by Earlier Flood. (8-5-57)



Fig. 49: Wayne Co.: Middle Section after 10 Months. (8-5-57)

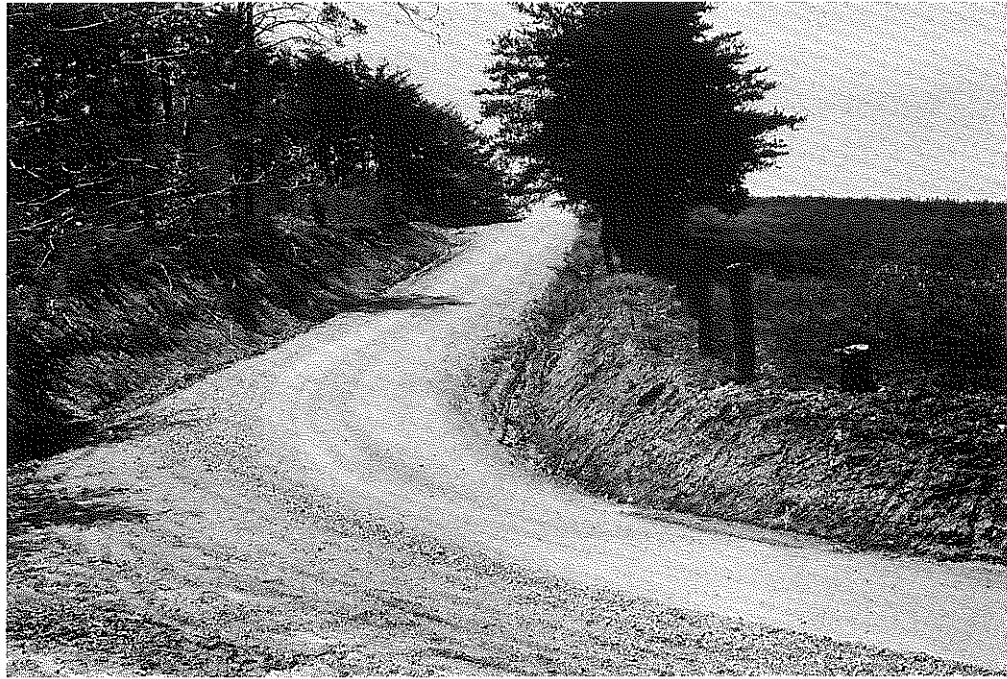


Fig. 50: Madison Co.: Sharp Curve Where Severe Wear and Raveling have Occurred, after 7 Months. (4-24-57)



Fig. 51: Madison Co.: Section Where Culverts Were Installed. Some damage due to flood has occurred. Wheel-tracks show considerable deformation which may have been caused by heavy logging trucks. (4-24-57)



Fig. 52: Madison Co.: View of Curve Shown in Fig. 50, after 10 Months. (8-5-57)



Fig. 53: Madison Co.: View of Section Where Culverts Were Installed, 3 Months Later. Some patching has been required. (8-5-57)

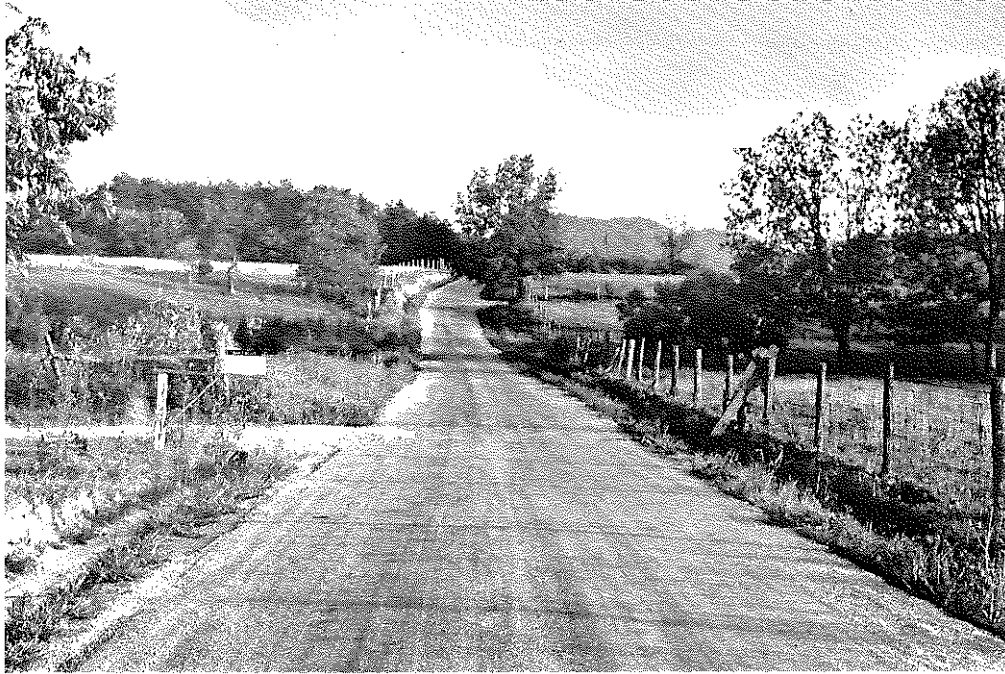


Fig. 54: Madison Co.: One of the Better Sections, after 10 Months. (8-5-57)



Fig. 55: Montgomery Co.: Typical Section before Stabilization. Bench in foreground is ledge of bedrock covered by black shale.



Fig. 56: Montgomery Co.: Granular Stabilization, Single Seal, after 6 Months. (3-13-57)



Fig. 57: Montgomery Co.: Shale Outcroppings in Ditches and Near Roadway Surface. These cause poor drainage and instability. (3-13-57)



Fig. 58: Montgomery Co.: Shale Outcropping and Poor Side Drainage, which Cause Poor Performance. (5-27-57)



Fig. 59: Montgomery Co.: Section Similar to that Shown Above. (5-27-57)



Fig. 60: Montgomery Co.: Curve Showing Wear and Raveling. (8-20-57)



Fig. 61: Montgomery Co.: Section Showing a Few Pot-Holes. However, condition is generally good. (8-20-57)



Fig. 62: Montgomery Co.: Section Affected by Underlying Shale and Poor Drainage. (8-20-57)



Fig. 63: Montgomery Co.: Same Section as Above Foreground, but Looking in Opposite Direction. (8-20-57)



Fig. 64: Lawrence Co.: Soil-Cement, Single Seal. Section was narrow, with bedrock outcropping through subgrade on hill in foreground. (10-24-56)



Fig. 65: Lawrence Co.: Across Upper Laurel Creek Bottom. Section in middle foreground remained unstable. (10-24-56)



Fig. 66: Lawrence Co.: Showing Unstable Fill near Middle of Project, after 6 Months. (3-13-57)



Fig. 67: Lawrence Co.: Same Section Shown in Fig. 64 during Construction. Slopes and roadway have eroded, most of the loose seal stone has been washed away. After 6 months. (3-13-57)



Fig. 68: Lawrence Co.: Similar Section, after 6 Months. Note back slopes sliding onto roadway. (3-13-57)

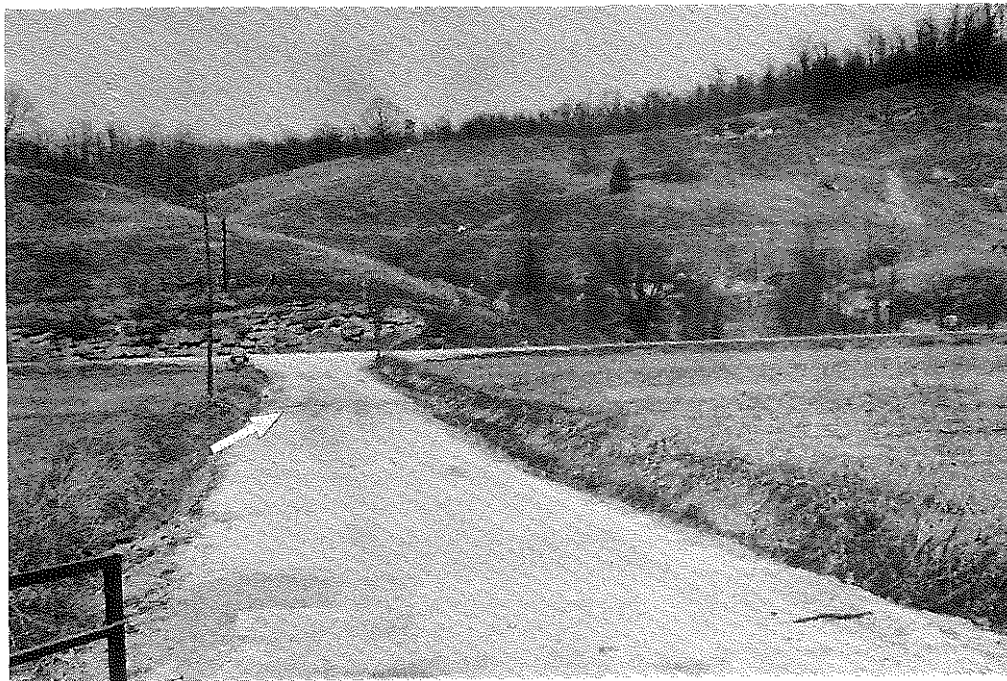


Fig. 69: Lawrence Co.: Creek Bottom Section, after 6 Months. Bridge approach had been inundated by flood. Note unstable area indicated by arrow. (3-13-57)



Fig. 70: Lawrence Co.: Narrow Section along Creek Bluff, Badly Eroded. (5-2-57)



Fig. 71: Lawrence Co.: One of the More Stable Sections, Showing Failure of Seal to Stick. (5-2-57)

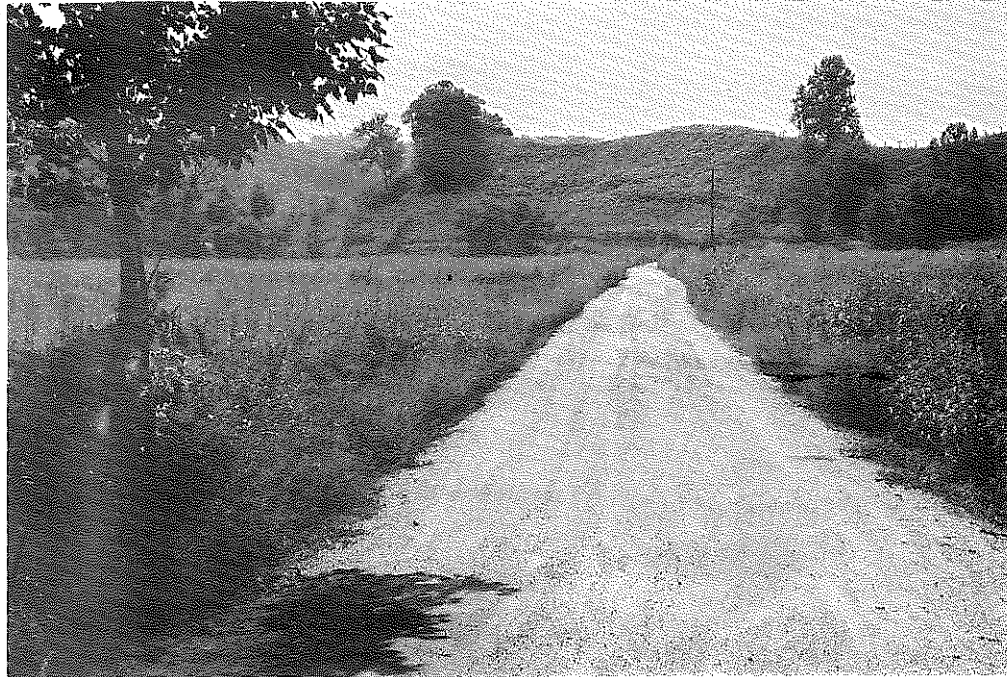


Fig. 72: Lawrence Co.: Recent Picture of Entrance to Project. Portions of this section did not stabilize. (8-20-57)



Fig. 73: Lawrence Co.: Section with Severe Loss of Seal Coat. Base seems sound and in good condition. (8-20-57)



Fig. 74: Lawrence Co.: Narrow Fill and Loss of Seal Coat. Base here is in very good condition. (8-20-57)



Fig. 75: Lawrence Co.: Same Section as Shown in Figs. 64 and 67. (8-20-57)



Fig. 76: Johnson Co.: W. Van Lear. Trav-L-Plant Connected Directly to SS-1 Transport. SS-1 was mixed in single pass, re-blended later. Existing roadbed was scarified preparatory to mixing with emulsion, no additional granular material required. (10-29-56)

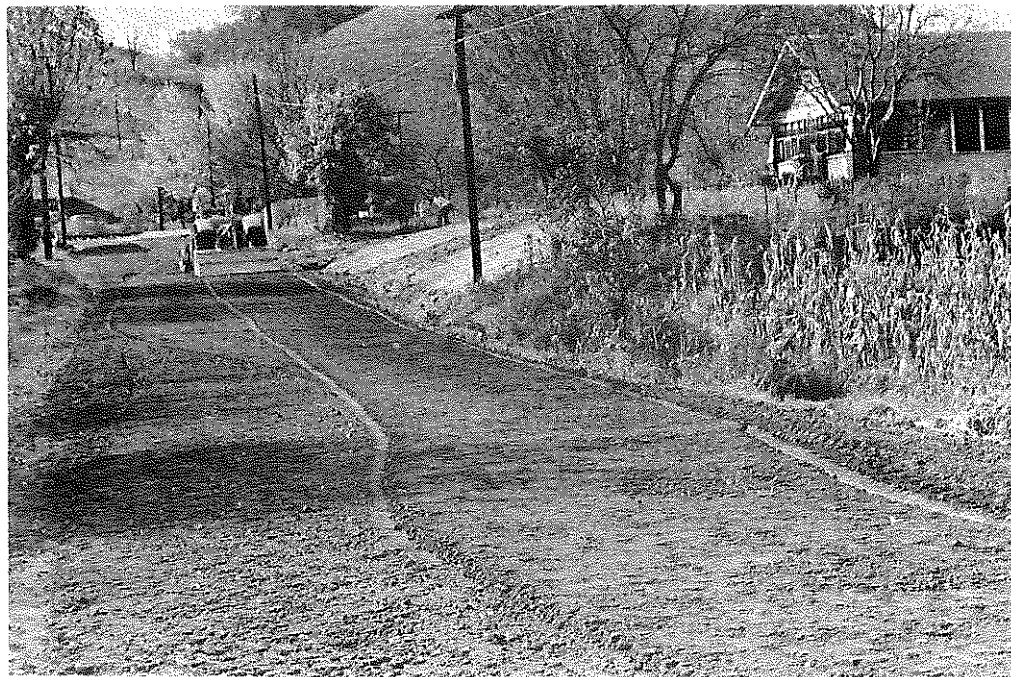
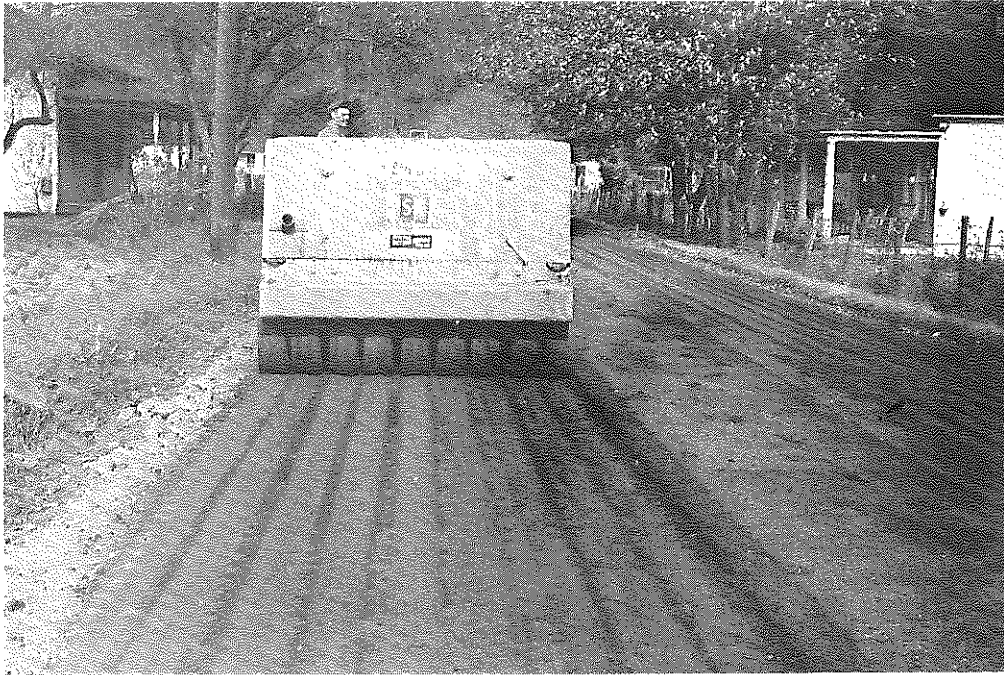
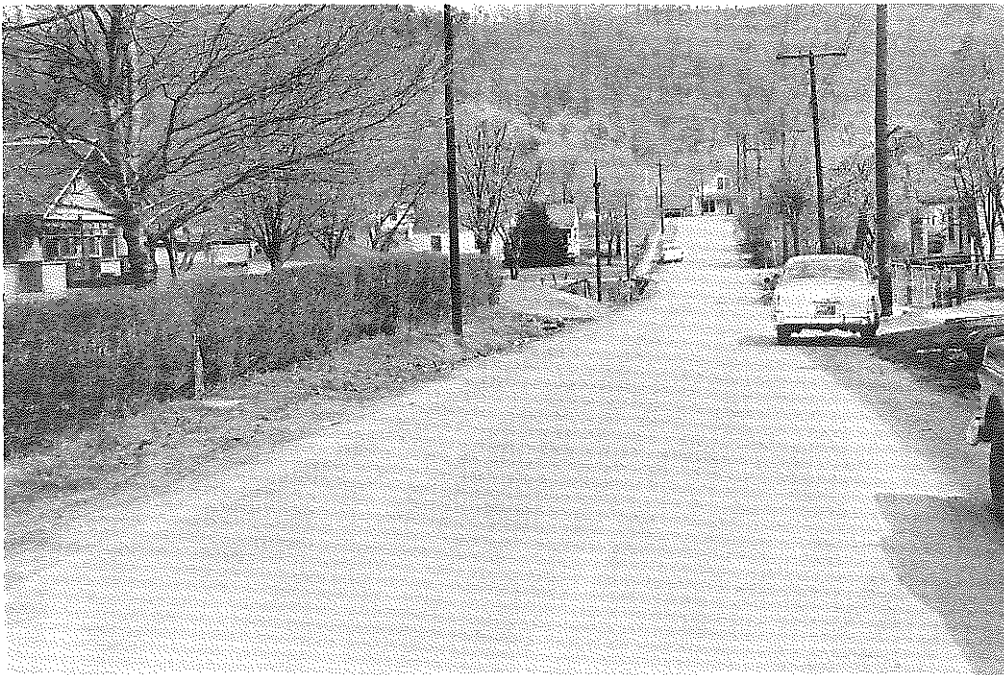


Fig. 77: Johnson Co.: Final Blending Preparatory to Compaction. (10-29-56)



**Fig. 78: Johnson Co.: Compacting Street in W. Van Lear.
(10-29-56)**



**Fig. 79: Johnson Co.: Street in W. Van Lear after 6 Months.
A few pot-holes have developed. Note absence of side ditches.
(3-13-57)**

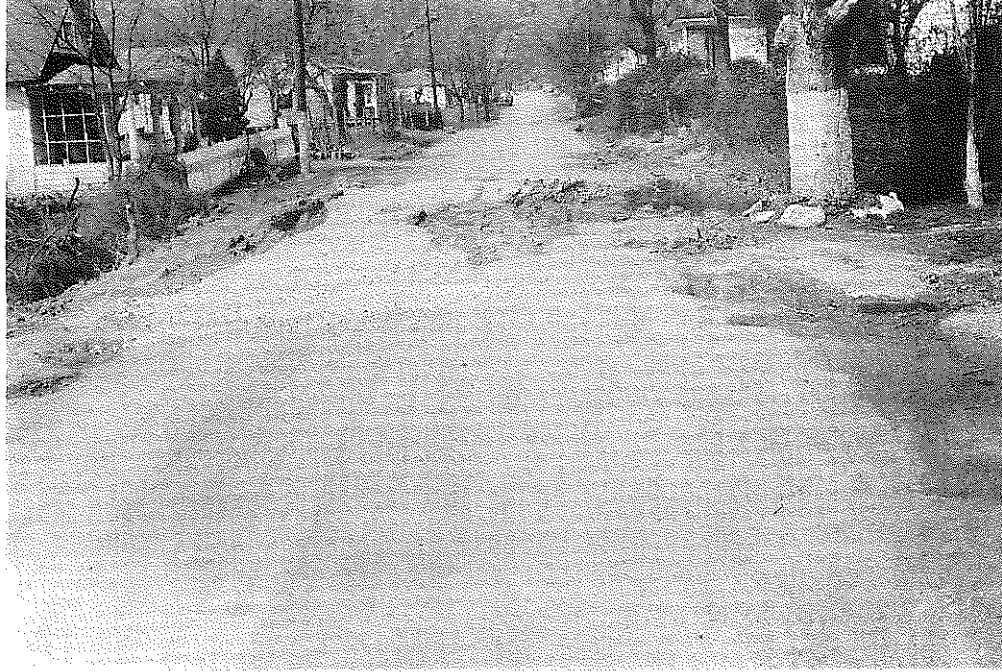


Fig. 80: Johnson Co.: Poorly Drained Section, after 6 Months. Roller bogged down here during construction. (3-13-57)

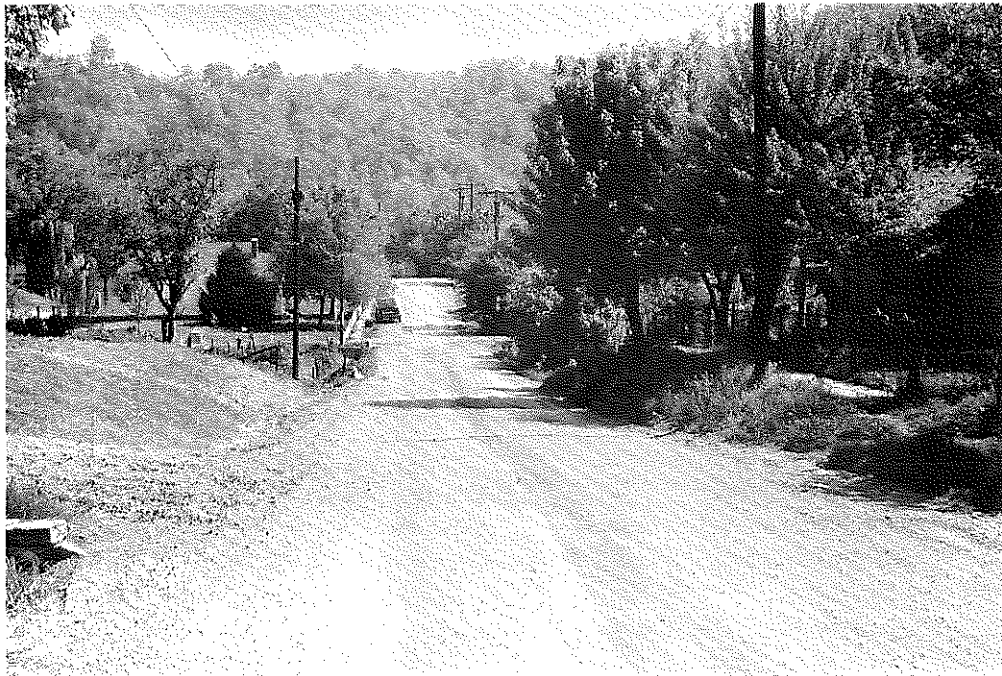


Fig. 81: Johnson Co.: W. Van Lear, after 7 Months. Softness has developed in area shown in foreground. (5-2-57)

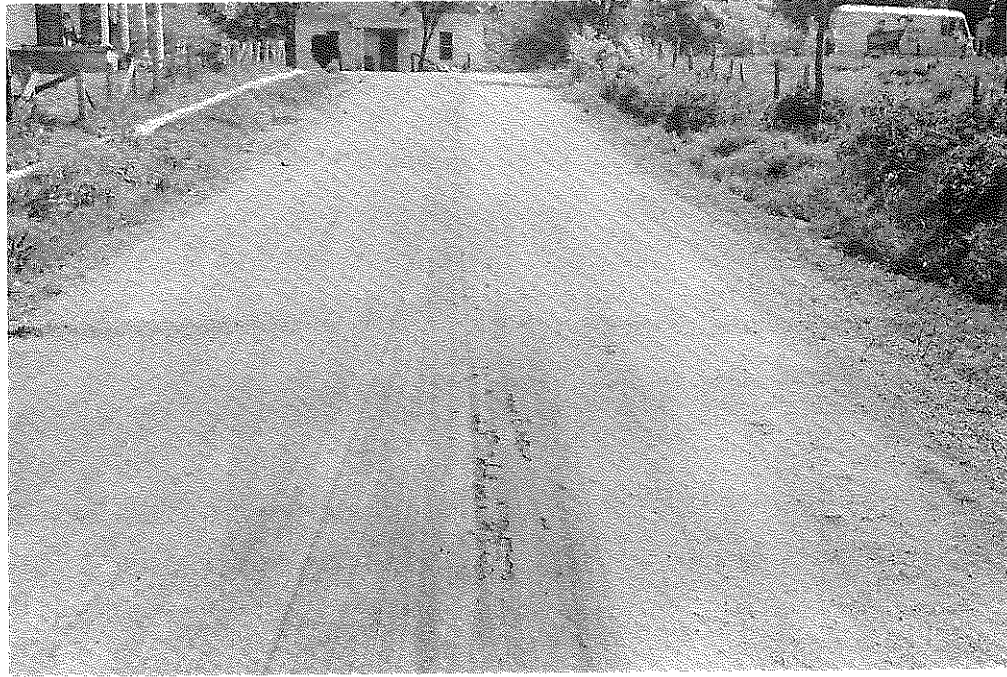


Fig. 82: Johnson Co.: Cross-Street, W. Van Lear. Seal asphalt bleeding through tended to stick to tires and to peel off the base. (5-2-57)



Fig. 83: Johnson Co.: Raveling and Pot-Holes in W. Van Lear Section. Maintenance crew adding more rock to bog shown in Fig. 80. (5-2-57)



Fig. 84: Johnson Co.: Same Street Shown in Previous Fig. Softness occurred at one spot because of clay pocket in the left foreground. (8-20-57)

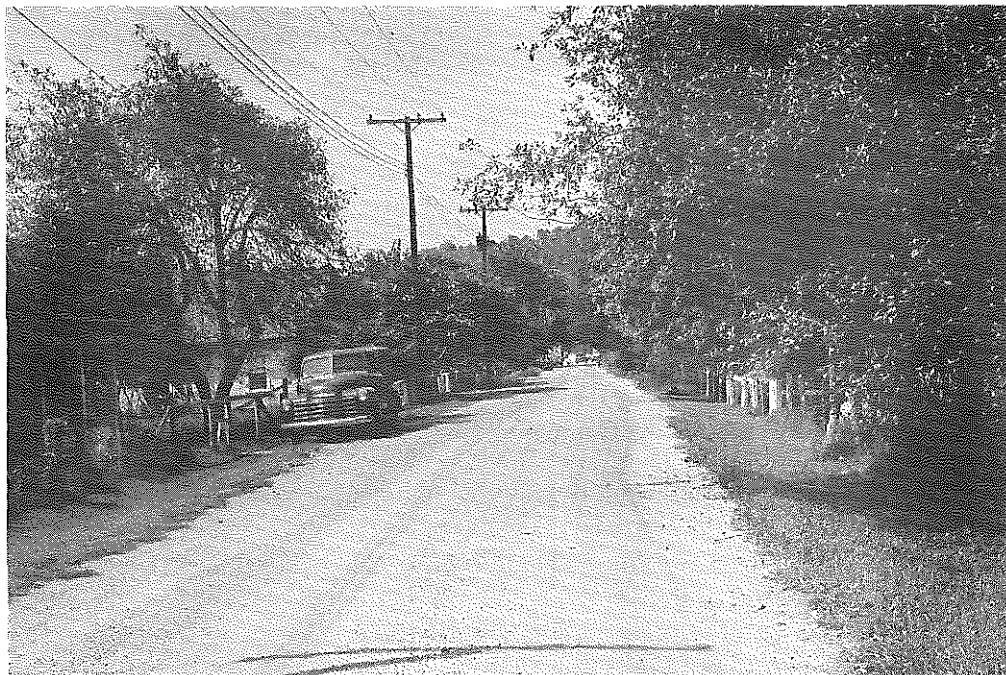


Fig. 85: Johnson Co.: Street Showing a Few Soft Spots and Pot-Holes but no Extensive Failure. (8-20-57)



Fig. 86: Johnson Co.: Short Cross-Street in W. Van Lear. Several streets such as this were stabilized but none of them carries much traffic. (8-20-57)



Fig. 87: Johnson Co.: Section Last Stabilized. This received a heavier application of SS-1, and some softness has resulted. (8-20-57)